

ANODIZING



Using an aluminum part in its natural state is an obsolete practice since the beginning of last century when the investigation into anodizing yielded good results. After the investigation into anodic aluminum treatment, the discovery that the process makes an aluminum part very resistant to damages and also provides a decorative film on the surface of the substrate informed the decision to continue with aluminum anodizing.

Since early 1950's, many patents about anodizing aluminum for decorative purposes has come into existence. From the beginning, many people have been paying attention to the anodic process which uses direct current or alternating current on sulfuric, oxalic or chromic acid working as the electrolytes. As a result of the above process, engineers discovered that if additives like metal salts in the form of nickel, arsenic, copper, silver, bismuth, selenium, tin, and antimony, cause changes on the color of the oxide as well as the mechanical and physical properties.

As a result of this changes, Bengough's and Stuart's 1923 patent became the first one that is protecting Aluminum and all of its alloys by making them resistant to corrosion through anodic treatment. In 1963, another coloring method came up from Caboni involving two processes that follow a sequence of using sulfuric acid for anodization followed by applying an AC in a metal salt solution.

What is Anodizing?

Anodizing aluminum follows an electrochemical process that converts the surface of aluminum into aluminum oxide. The process of aluminum anodizing converts the surface of the metal into a durable, decorative, corrosion resistant finish. Even though aluminum is very suitable for anodizing, some nonferrous metals like titanium and magnesium can also pass through anodizing.

The anodic oxide structure comes from the aluminum substrate which is composed of aluminum oxide. The oxide which comes from anodizing is not like electroplating or painting. It integrates with the aluminum substrate to prevent peel or chip. The oxide comes as a highly porous structure which allows for some secondary processes like sealing and coloring. Perhaps, the integration of the acid bath solution into the aluminum to form an oxide is why anodizing is always referred to as conversion coating. If paint or plating is used on a metal, the coating will just sit on the metal surface, but with anodizing, there is a total integration between the coating and the substrate to convert it to an oxide.

To complete aluminum anodizing, the part is immersed in an acid electrolyte bath as a low-voltage direct current through the cathodes on the tank sides.

There are three types of anodizing available in the industry. The type 1, type 11 and type 111.

Type 1 or Chromic acid anodizing is the oldest of the three types. It works well for some alloys and very popular amongst aerospace and defense industry. However, the type one anodizing has grown obsolete because the chromic acid which forms the solution is an unfriendly environmental acid and as such, type 1 anodizing is growing extinct. Common type 1 anodizing applications include a military application.

Type 11 and Type 111 anodizing originated from MIL-A-8625 (Military specification). Both type 1 and type 11 anodizing are popular because they provide hard coatings on aluminum. Type 111 uses a lower temperature, more expensive and also more difficult to achieve than type 11. Also, Type 111 or hard anodizing provides a thicker coating than type 11 approximately "0.002 vs. 0.0006". As a result, type 111 anodizing is very resistant to heavy wear and scratching.

Type 11 or sulfuric anodizing application include computers, aerospace, automotive and architecture. Some type 111 or hard coat anodizing application include equipment for food packaging, exterior applications, and photocopier paper rolls, etc.

The last type of anodizing you can find in the industry is the architectural anodizing. It operates almost like type 11 but has a slight difference because it makes use of metallic ion dyeing to make the anodized aluminum colorfast while under the sun.

Some aluminum anodizing applications include:

1. Furniture
2. Architectural and Structural categories
3. Residential and Commercial building products
4. Appliances
5. Artwork and jewelry
6. Equipment for food preparation
7. Boats and Sporting goods
8. Components of motor vehicles

Few of the end products which use anodized aluminum are as follows:

1. Interior decoration
2. Exteriors of buildings like roofing systems, storefronts, curtain walls, etc.
3. Pans, grills, display cases and coolers for food industries
4. Exterior panels of aerospace vehicles, electronic products and clocks, fire extinguishers, solar panels, picture frames, bathroom accessories, photo equipment and telephones.
5. Anodized aluminum is also in leisure industry products like camping and fishing equipment, boats, golf carts, etc.
6. You can find anodized aluminum in beds, tables, storage chests for offices and homes, file chest, etc.



7. Products like awnings, dust covers, vents, window frames, bathroom accessories, light fixtures, storm doors, mailboxes, wall switch plates, etc.
8. Motor vehicles components like wheel covers, nameplates and control panels also contain anodized aluminum.
9. Other appliances like dryers, coffee brewers, range, refrigerator, microwave equipment and televisions contain anodized aluminum.

The reason for using anodized aluminum parts in making all these products is because, it provides an aesthetical result with increased durability provides interesting design opportunities for builders, architects, specifiers, artists, specifiers and product designers.

Why Anodizing?

Anodized finishes have enhanced the importance of aluminum parts in the industry. Many people are now using more of aluminum materials in producing many commercial, industrial and consumer products.

There are many reasons for anodizing aluminum which includes making the parts stronger for production of many products.

Reasons for anodizing

1. Anodizing protects aluminum parts from corrosion. It makes aluminum to withstand salt-spray and other anodizing tests very well.
2. The anodizing process provides finishes that are environmentally friendly. It makes the aluminum recyclable. Also, the production processes make use of inorganic chemicals that don't have a dangerous impact on the environment.
3. Anodizing provides a thin coating on the aluminum; if you compare anodizing to powder coat and paints, the former gives a thickness that is acceptable for products parts.
4. Some anodizing types like that of architectural anodizing have colors that can withstand sunlight and remain almost like that indefinitely.
5. Anodizing aluminum is inexpensive; if you are operating on a low budget, it is advisable to use anodizing instead of powder coating or painting. When you compare the cost implication of the three, anodizing is the cheaper option.
6. It makes the aluminum part of being good insulators of electricity. If you combine anodizing with other coatings, you can use it for masking low-voltage currents.
7. Anodizing makes aluminum hard, durable, resistant to abrasion and long-lasting. When you coat aluminum through anodizing, you can be sure that it will not chip or peel. It turns the aluminum surface very hard than when a conventional paint is used.



There are many advantages of using anodized aluminum parts to manufacture commercial, industrial and consumer products. Such advantages include:

1. Anodized aluminum makes it attractive, provides a durable exterior like curtain walls, roofs, floor escalators, ceilings, lobbies and staircases in commercial buildings and skyscrapers around the globe.
2. Aluminum is also used in constructing computer hardware, used for exhibit displays during trade shows and also used for scientific instruments.

3. Anodized aluminum parts are used in many consumer products, building materials, and home appliances.
4. Anodizing aluminum used for satellite provides the protection it needs to withstand the space environment.
5. It protects the environment from industrial pollution as it only produces little or no harmful effect on air, land, and water.

How to do Anodizing

Before starting the anodizing process, you will first hang the aluminum part on stripped titanium or aluminum racks so that there will be adequate electrical contact. All through the process, the parts will remain on the racks which will be suspended in all the tanks for the process.

The aluminum anodizing process starts from:

1. Dipping the parts in the hot tank of cleaning agent to ensure the removal of every dirt on the surface of the aluminum part.
2. After the soaking, rinsing the aluminum part will follow to prevent the contamination of anodizing solution in the tanks for the other steps.
3. When the rinsing is finished, de-oxidizing the aluminum parts in a tank containing the acid solution which may be chromium, nitric, and sulfuric or phosphoric acid to remove the thin and non-uniform aluminum oxide surface.
4. After applying the acid solution, rinsing the aluminum parts for the second time follows to prevent tank contamination.
5. The next step after the second rinsing is etching which you can perform by suspending the aluminum part in another tank with the sodium hydroxide solution to remove the natural shine of aluminum and achieve a soft and textured look.
6. Afterwards, the aluminum part enters the anodizing tank containing a water mixture and diluted acid which can permit electrical flow of current. At this point, the percentage of the solution, the type of acid used and the temperature all play important roles and the choice for each of them depends on the color and finish required for the end product. Connect the electrical circuit's negative leg to the rack containing the aluminum part. Also, connect the positive circuit side to the cathode (s) that is responsible for introducing electricity to the anodizing tank.

The quantity and where to place the cathodes may not be the same in every anodizing because it depends on the shape, the size and the total square footage of the aluminum surface you want to anodize. After anodizing, you will notice that the aluminum surface closest to the cathode gets a thicker anodic coating. If it is a normal Type 11 anodizing, using a direct current source that can produce 24 volts will be more effective if the voltage remains between 18 and 24.

Also, the total current that you will apply to the tank will vary according to the amount or wideness of the aluminum surface you want to anodize. The common measurement is for every square foot of aluminum surface, use 12 to 16 amps. During the process, the anodizing electrolyte solution becomes agitated so that there will be a uniform temperature in the anodizing solution. It takes one hour for the anodizing tank process to conclude.

After anodizing, dyeing becomes the next step. This is a process of adding color to the aluminum oxide. For better results, all you do is to dip the aluminum part into the dyeing tank where the mixture of water and organic will add the color requirements. The dye differs depending on the time and temperature which the immersion will run through.

After dyeing, sealing follows to ensure that the colorful aluminum surface will not stain or bleach under sunlight. If you omit to seal, the outer surface which is porous will have a lower resistance to corrosion. For coatings that are not dyed, the aluminum part after anodizing will go into the boiling de-ionized water and stay inside for twenty to thirty minutes. This dipping into boiling water will change the pores of the aluminum oxide without structure into a solid crystalline hydrate form. However, if the aluminum oxide is dyed, it will stay in the nickel acetate solution tank for three to five minutes to conclude the sealing process.

If it is hard anodizing/type 111 anodizing, the mixture will include oxalic and sulfuric acid. For the temperature, a low temperature, higher current, and much higher voltage will complete the entire process. After anodizing, you will achieve a gray oxide that is two to three MLS, dense and resistant to corrosion and wear.

If you don't want to use rack anodizing process, you can anodize the aluminum parts in bulk, but it will be for small parts or those aluminum parts with irregular shapes like ferrules, rivets, and medical hubs.

For this kind of aluminum parts, you will make use of perforated titanium, aluminum or plastic baskets. No matter which type you use, anodizing ensure a great aluminum finishing in the industry. If you don't want to use the above options, you can anodize aluminum using the coil method of anodizing. In this anodizing, coiled aluminum is first pre-anodized so that the finishing cost will be lower, the production time will also reduce, and materials handling will reduce as well.

Apart from the main anodizing process, there are currently six coloring processes which you can follow to achieve good results as well although not comparable to full anodizing.

1. Surface coating

The process of this coloring method follows:

Pretreatment, Grounding, Color Coating, Curing of the lacquer coat.

Structure:

1. Grip coat ca. Al oxide hydrate Al-Cr phosphate 1 μ m
2. Lacquer coat 30-80 μ m organ. Polymers
3. Color pigments to be distributed in the lacquer coat

Shades; there are many color shades you can achieve with this process. There can be white and several degrees of gloss. The appearance of the surface; it will maintain the metallic nature of the aluminum lost. Also, there will be pigments under the surface of the aluminum.

Overall resistance; the resistance will be great, but that will depend on the pigment quality and the binder type. In some cases, you can observe chalking.

Chemical stress; it can resist alkaline materials, corrosion and may show signs of chalking a few years later.

Mechanical stress; the material may not show resistance to mechanical stress as much as anodized aluminum. Also, you may notice that the lacquer coat may flake in some cases.

Color repair; you can repair the color without dismantling the whole unit, but it will not be so easy. Achieving the right gloss/shade will be very problematic and adhesion to repair may not be the same.

Main applications; the main applications of the surface coating is buildings that have high representative character.

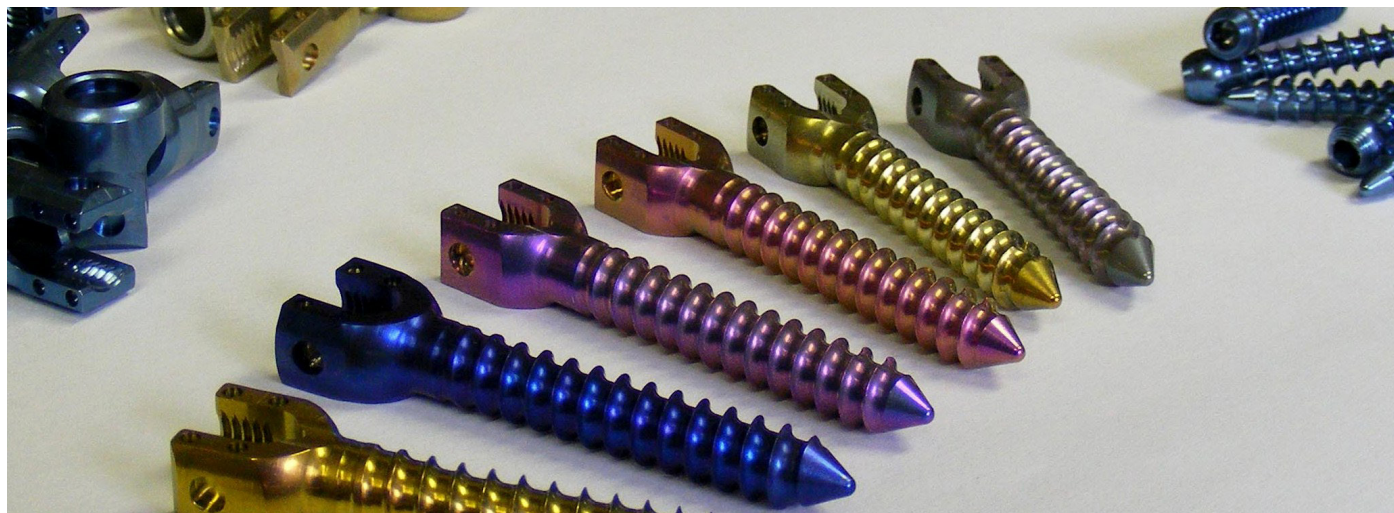
2. Integral coloring

The process of this coloring method follows:

Pretreatment, Anodizing (organic acid+ special alloy), Sealing

Structure:

- i. Distribute the coloring matter in hard Al oxide which is strongly bound with the anodic film thickness of 15-40 μm



Shades; you can use brown, gray, slate, bronze, etc. but no white.

Appearance of the surface; it will retain the aluminum metallic character

Overall resistance; there will be no chalking, durability is unlimited, and the overall resistance is outstanding.

Chemical stress; it is usually sensitive to all construction materials that are alkaline

Mechanical stress; it is extremely resistant, and there will be no flaking. Also, the integral coating is harder than surface coatings.

Color repair; to repair the colors, you must dismantle the whole unit before successfully repairing it.

Main applications; the main applications of the surface coating is buildings that have high representative character.

3. Organic dyeing

The process of this coloring method follows:

Pretreatment, Anodizing (no special alloy), Dyeing (using highly-fast dyes), Sealing

Structure:

Coloring matter in some cases will be an organic dye which you can incorporate all-round the coating that is tightly bound to your aluminum material. The minimum thickness of the anodic film will be 20 μm

Shades; you will achieve spectral colors like deep red, deep blue, deep yellow, deep black and deep turquoise. There will be no bronze, gray or brown.

The appearance of the surface; the aluminum will retain its metallic character and will also have a high brilliance.

Overall resistance; impressive

Chemical stress; it will be sensitive to every alkaline construction material

Mechanical stress; it will be like electrolytic dyeing, and there will be no flaking. Also, the coatings will be harder than when you do surface coating.

Color repair; you must dismantle before repairing

Main applications; colorful and high representative buildings

4. Inorganic dyeing

The working method for this process is as follows:

Pretreatment, Anodizing (no special alloy), Dyeing (using fast inorganic dye salt that has no current 1-or 2- bath), Sealing

Structure:

Coloring matter will be heavy metal oxide hydrate; Co, Fe, Mn. which you will incorporate in the outer region of the coating.
The minimum thickness of the anodic coating will be 20µm.

Shades; gold tones, pale bronze or dark bronze, muted

The appearance of the surface; the metallic nature will remain, the film will be duller with gold tones.

Overall resistance; Great

Chemical stress; alkaline materials sensitivity

Mechanical stress; there will be no flaking. The coatings are harder than mere surface coatings

Color repair; must dismantle before repair

Main applications; buildings that have high appearance requirements.

5. Electrolytic coloring

The method for this method is as follows:

Pretreatment, anodizing (no special alloy), dyeing using A.C and metal salts, Sealing or Coating with a colorless lacquer, Curing.

Structure:

Coloring matter at the base of the pores consisting of highly dispersed metal form which is bound to your aluminum material.
The minimum coating thickness will be 20µm.

Shades; gray, brown, burgundy, bronze, slate, pink, no white and no spectral colors.

The appearance of the surface; retaining the character of the aluminum.

Overall resistance; very outstanding and no chalking.

Chemical stress; highly sensitive to alkaline materials

Mechanical stress; no flaking but less hard in if you compare to color-anodized aluminum coats but harder than normal surface coatings

Color repair; you can't repair unless you dismantle it unless alien retouching.

Main applications; buildings with high appearance requirements.

6. Electrolytic coloring +Organic dyeing.

This coloring method follows:

Pretreatment, Anodizing with no special alloy, dyeing with inorganic or highly-fast organic dyes, Sealing

Structure:

There will be coloring matter at the pores base and another in the coating. The thickness of the anodic coating will be 20 µm

Shades; unlimited, muted shades and no white

The appearance of the surface; it will retain the surface appearance and the metallic character of the aluminum.

Overall resistance; very great and no chalking

Chemical stress; alkaline material sensitivity

Mechanical stress; just like electrolytic dyeing; no flaking and still harder than a normal surface coating.
Color repair; must dismantle before repair unless alien retouching.
Main applications; high appearance requirement buildings.

Anodizing troubleshooting/Defects

While anodizing aluminum, there are cases when there are issues like spots omitted while anodizing. Imagine anodizing an aluminum only to discover that there were regions that didn't get the anodic coating required from the anodizing process. These kinds of defects are often caused by slight contamination of the aluminum part surface especially when the anodizing process is in full swing.

When contamination occurs, it will stand as a hindrance to the acid getting to the surface of the aluminum part. The most common cause of this aluminum surface contamination can be as a result of the improperly cleaned surface during pretreatment.

Apart from surface contamination, there are other anodizing defects which you should know to avoid:

1. Acid Corrosion

This is another anodizing defect that occurs during the anodizing process. You can only notice this defect after etching, anodizing, coloring, and sealing. This defect is random and often isolated. It appears in large and also deep pits. You should easily detect acid corrosion product in the pit if you observe it before you go to etching and then anodizing. However, if they have passed through etching and anodizing, they will get cleaned and also contain anodic film.

The main cause of acid pitting defect is when you splash the aluminum parts with acids accidentally especially when in storage in the plant. Due to this defect, people are not using chlorinated solvents for degreasing like before. Through the process of hydrolysis, the formation of hydrochloric acid is possible in solvents. Since droplets of trichloroethylene vapor contain HCl, they can cause pitting.

When such defect occurs, there is almost nothing you can do. So the best approach to avoiding acid pitting is to maintain better storage and housekeeping of the aluminum anodizing plant.

2. Alkaline Corrosion

This is another anodizing defect that occurs during the anodizing process. Alkaline corrosion also becomes after etching or anodizing. You will notice a well-rounded pit that has no intergranular corrosion. The main cause of this defect is mortar, splashes of wet alkaline or cement. Sometimes, spilling of caustic chemicals or etch spray can also cause alkali pitting. When there is an alkali pitting, it is impossible to revamp the aluminum section so, make sure that you provide proper storage and housekeeping as well.

3. Anodizing Burn

This is also a defect that can occur during the anodizing process. This type of defect shows non-uniformity of the anodic coating, and you can notice it after anodizing the aluminum. The sign of anodizing burn is usually bright areas surrounded by black or noticeably darker area on the anodic coating. Mainly, you may not see any anodic film in this area, but if there is, it will be very soft.

The main cause of anodizing burn is an excess of current density, insufficient movement or agitation of the electrolyte across

the piece. Also, when there little electrical contact between the jig or the anodizing rack and the aluminum you want to anodize.

When an anodizing burn occurs, there are few things you can do to remedy the situation.

1. Check the concentration of the electrolyte to be sure that the temperature is appropriate
2. Improve the electrolyte agitation
3. Reduce the current density for the anodizing
4. Increase the electrical contact between the aluminum and the rack.

4. Chloride Corrosion

This defect occurs during the anodizing process, and it also takes the form of acid pitting. You can notice chloride corrosion after anodizing the aluminum part. The pits will appear like a star on the face of all the samples. Usually, the pits will be deep and black but with no anodic film.

The cause of chloride corrosion is when the critical level of chloride 80ppm which is measured as the Cl⁻ ion in a sulfuric acid electrolyte is exceeded. As you exceed the level, highly active aluminum will experience corrosion as you continue with the anodizing process. Oxalic acid electrolytes are usually more sensitive to Cl⁻.

To eliminate the acid corrosion defect, use deionized water for anodizing electrolyte make-up and top-up. Also, use it for other important processes or rinses.

5. Color differences

Well, after anodizing and coloring, you may notice that there was non-uniformity in the color of the aluminum part. You just need to look at the aluminum part to detect that the color if not uniform. When you notice that the range between the extrusions is far from what the upper and lower limit should be, then, you will know that the color match was poor.

So many things can cause color differences after coloring. Some of the common causes are:

1. Some of the extrusion may have taken more pigment or dye than others.
2. Differences that occur in the anodizing parameter.
3. Differences or inconsistency of the alloy
4. Incorrect conditions during dyeing
5. Lack of electrolytic coloring process control.

When there is a color difference on the anodized aluminum there few things you can do like:

1. Check the anodizing solution concentration, time, PH and temperature.
2. Check the dye solution concentration, pH to ensure that there is no contamination with the chlorides and sulfates.
3. Check the time and temperature of dyeing
4. Ensure that the pH of the post anodizing rinse is under 2,0.5.
5. If it is an electrolyte coloring, this defect can arise if there is wrong coloring contamination or condition during coloring electrolyte with sodium. In such cases, you can do the following:
6. Control the coloring operation within the limits of the process practices and the electrolyte concentration as recommended by the supplier.
7. Check where the variation is occurring like within a load or variation from load to load.
8. If it is from load to load, check out the consistency of the anodizing practice and coloring practice as well.

9. Afterwards, strip and then reprocess the affected extrusions.

6. Comet Tails

This defect occurs during the anodizing process and fall specifically under the pretreatment chemical polishing. It also shows non-uniformity, and it is visible after brightening or anodizing.

The defect appears in the form of vertical gas marks or comet tails, and the cause of this defect is when there is an evolution of hydrogen gas when you are doing the chemical polishing. The defect often starts with the dried-on polishing compound. When this defect occurs, improve your degreasing process so that you can remove every trace of polishing compound. Also, move the jig when you are carrying out the chemical polishing process

7. Crazing

Another anodizing defect that occurs during the process showing non-uniformity that will only be visible after the sealing process. It appears like hairline cracks which you will notice in the coating after sealing.

The cause of crazing is usually stress from the anodic oxide coating through the transfer of profiles from the rinse tank to the sealing tank. As a result of the differences that exist in the thermal expansion coefficient between the coating and the aluminum, hairline cracks develop. Also, cracks may occur as a result of mechanical deformation of extrusion through impact or bending. This defect enhances because of high current densities, a thick oxide film and low temperature in the electrolyte. The remedy for this type anodizing process defect is to do stabilizing heating of the profiles to remove the stress. Also, you should reduce the current densities. Make the electrolyte temperature to be 20 degrees centigrade. Let the anodic film thickness remain 30 μm and also lower the thermal shock by dipping the anodized aluminum parts in the water at a temperature of 70 degrees Centigrade before you immerse it in the process boiling water seal.

Avoid heat thickening anodic films to be above 120 degrees centigrade. If you need to bend the extrusion, do it before the anodizing process starts. If you want to reprocess the part, strip the anodic film and start the anodizing on the aluminum again.

8. Etch Staining

A processing defect that shows non-uniformity after etching or coloring. To identify this defect, you will see a stained extruded section after the process of etching. Sometimes, you may not immediately identify it after etching until after some time as you go ahead with the anodizing process.

Etch staining can come up as a result of drying of the etch solution on the surface of the extruded section while transferring it to the post-etch rinse. Also, if the extrusion is not properly cleaned or rinsed after etching, staining can occur. If there was a lot of time lapse between the time of etching and the time of rinsing, staining might occur. Other causes of etch stain are; speed of crane, like if the crane is moving slowly if the composition of the etch solution is wrong. Also, when the temperature of the surface of the profile is too high due to wrong etch composition, or if there is no cooling of the tank and the profiles are of a thick wall. Finally, if the jig is poor and the cleaning is less than adequate, etch staining will occur.

The remedy to this anodizing defect to ensure that there is an adequate wetting agent in your etching solution. Then make sure that you improve the time for the transfer from the etching stage to when you will do the rinsing after etching.

Also, make sure that the temperature of the etch solution is normal and not higher than required. Don't allow it exceed 60 degrees centigrade. Let there be good as and quick rinsing or cleaning of the surfaces after you finish the etching process.

9. Gas Trapping defect

This defect cause non-uniformity of the anodic coating after coloring or anodizing. What you will see is random spots that are not colored has a different hue or appear lighter especially on the downside of the workpiece on the rack. Usually, you will notice that the film is thinner. Dyed finishes or the electro-colored finishes may be lighter or even darker based on the coloring method you used.

The cause of gas trapping defect is when gas or air bubbles from the agitation system or electrochemical reactions evolved gas is trapped under the racked workpiece.

When this defect occurs, make sure that you arrange the workpiece on the rack in such a way that there will be no inverted channels or horizontal flat surfaces under it. You can recover it if you strip the affected piece and reprocess it entirely. Put them on the rack carefully and appropriately so that gas or air trappings will not occur.

10. Hot spots defects

You will notice a dark /gray/black rough patches at random or regular intervals along the length of the extrusion. If you etch that defective sample in a 10% NaOH solution at a temperature of 60 degrees Centigrade, you will observe black and heavy smut where the hot spot appeared.

The cause of this hot spot is metallurgical and no as a result of anodizing. It occurs when there is coarser Mg₂Si precipitation in the areas where the hot spots appeared. Also, it can occur as a result of differential cooling on the walking beam or run-out table of the extrusion. Normally, you will notice that the hard texture of the aluminum where the black spot occurred will be lower than the hardness of the other parts of the extrusion.

What you need to do is to make sure that the time which the hot sections will stand on the walking beam or run-out table will be under your control. If the temperature is above 230 degrees centigrade, the problem will be eliminated. Also, if you use purpose-designed materials and forced air-cooling materials like Railco or Kevlar, you can eliminate the problem as well.

11. Insufficient degreasing

Another anodizing process defect which causes non-uniformity after etching or brightening is when there is insufficient degreasing. The main cause of this defect is when there is a poor solution for the degreasing process. Example, if the temperature is too low or the grease or oil remain on some areas of the aluminum sections you are anodizing.

When there is insufficient degreasing, renew the solution or extend the time of the treatment. You can also increase the temperature if you do not extend the time. Recovery of insufficiently degreased workpieces is very difficult.

12. Pick Ups

This is an extrusion defect that you will notice after anodizing. It usually shows scuff marks with different intensity. When the defect is severe, there will be a deposit at the mark's end. This pick-ups defect sometimes occur on many extrusions.

Some of the things that can cause this defect are the extrusion speed, condition of dye surface and extrusion temperature. When you notice the defect, just make sure that you have more control on all the extrusion parameters that influence the quality of the surface.

13. Pitting Corrosion

This defect often develops when the part is in service. It appears like little holes penetrating the anodic film. The cause was usually when you did not follow the specifications for forming the anodic fil or if there is contamination in one of the rinsing

tanks or process tank after you are through with anodizing like the coloring tank. The main cause of this contamination is usually chloride from the tap or main water.

The things you can do to remedy the situation is to check the water make-up to ensure that chloride does not exceed 50 ppm. Also, avoid using the rinsing tank as a buffer tank but use Desmut tank for the buffer.

There are other anodizing defects that can occur during and after the anodizing process. Some defects like Polishing drag marks which you can remedy by making sure that the surface of the profile is free of all impurities, Rinse water corrosion which you can avoid by adding a small quantity of oxidizing acid like 0.5%, and Spalling which you can remedy by reducing coloring voltage.

Others like brightness differences, chalking, chatter marks, die lines, etch solution pitting, finishing Operation Streaks, Longitudinal Weld, and Transverse Weld. There are others like Patchy Colored Finishes, Mechanical Polishing Burn, Air Spots in Coloration, White Spots in Dye or Electrolytic Color and Non-uniform Anodized Layer are all anodizing defects that can occur during the process.

Hard Anodizing

This is an anodizing that follow an electrochemical process to harden the surface of an aluminum part by building an anodic substrate on the part as a form of protection. Hard anodizing is like the normal anodizing because both of them involve an electrochemical process. The main difference between hard coat anodizing and standard anodizing is that the former delivers a much harder, smoother and wear resistant surface than the latter.

The process of hard anodizing is not complex at all. An aluminum part called anode is dipped in a sulfuric acid electrolyte. A direct current (DC) of about 32 degrees Fahrenheit will then be applied to the anodizing bath tank where aluminum oxide will generate on the surface of the aluminum. This layer of aluminum oxide often penetrate deeply into the material and the time may take from 20 minutes to 2 hours depending on the coating thickness you require.

There are many uses for hard anodizing which include areas that require high resistant to corrosion and wear. For example, pulleys, boat parts, sprockets, pistons, etc. The best alloys that you can use for hard anodizing are alloys that range from 5000, 6000 and 7000 are the best for hard coat anodizing. Alloys that has high copper or silicon concentration are considered unfit for hard coat anodizing. The colors for hard anodizing is usually varying from brown shades to dark grey because of the thick and dense coatings.

Hard coat anodizing affects dimensions, the aluminum appearance and the decision to seal or not to seal. If the parts have compact dimensions, it will affect the final dimensions. Secondly, if the aluminum part was not dyed, the color of the aluminum part will change. This change will rely on the type of alloy and the level of thickness of the anodic coating. Some alloys turn bronze/gray after hard anodizing.

If it is a dyed aluminum, the common color you will use is black. However, there are other colors you can use, but that will depend on the thickness of the coating and the type of alloy you are using. As for sealing, it is not compulsory after anodizing depending on the key function of the hard coat anodizing application.

If it is strictly to achieve a high level of wear and abrasion resistance for the aluminum part, then you can forget sealing. But if the function is to achieve corrosion resistance without much need for abrasion resistance, you must seal it. Just be sure that you get specification or give sealing specification to your supplier.

Considerations of Hard Anodizing

Before engaging fully in hard coat anodizing, there are some things you have to consider to achieve good results.

1. The size of the aluminum part

Since you are doing hard anodizing, the dimensional change you will see will be like half of the coating thickness you applied. If you anodized the part to 50 microns, expect a dimensional change of 25 microns on every aluminum surface. As a result, you should factor in this dimensional change before matching. As the parts size increases on the outside, the bore will also shrink according to the same ratio and by the total thickness of the coating. Therefore masking may become a necessity.



2. Surface finish

If you must achieve wear resistance for all your components, then you must make sure that the surface finishes before the anodizing exercise is very smooth. Failure to achieve a smooth surface finish may cause raised spots to fracture off and fall between the sliding surfaces which may lead to a high level of wear.

3. Non-aluminum parts

Any attachment to the aluminum part like steel materials will be destroyed during the hard anodizing process.

4. Joins

Make sure that you avoid spot welded or riveted areas.

5. Earth point

If there is a need for the earth, mask it before anodizing because of the high resistance to electrical current by the coating. Also, you must mask it because removing it after anodizing will be very difficult.

6. Sharp edges

You are aware that anodizing occupies a perpendicular position on the surface. As a result, the edges at the outer sides may have some voids where the anodizing didn't touch while the sharp inner edges will have a crash as coating grows inside. Both cases will lead to defects in the hard coat anodizing finishing. Therefore, follow the guideline laid out in MIL-A-8625F so that you can avoid both "void" and "crash".

7. Mixed alloy

If you can, avoid having mixed alloys anodizing in hard coat anodizing. If you are doing ordinary anodizing, you can do it but not in this type. If you anodize two different alloys, one may anodize at a greater than the second one. The point is that a slight difference that may not matter in normal anodizing will be critical in hard anodizing.

8. Forming

If you must form or bend the product, do it before the anodizing process. If you wait after, the aluminum oxide formed from anodizing will just fracture or crack if you make any attempt to bend the part.

9. Sealed or unsealed

If your purpose for hard anodizing the aluminum part is to increase its wear resistance capacity, then leave the parts unsealed to maximize its wear resistance capacity. On the other hand, if you aim to increase the resistance to corrosion, seal up pore structure to ensure the highest level of resistance to corrosion. Apart from sealing applying a secondary coating over the pores will also do the trick.

10. Threads

The thread dimension changes during the anodizing process. To avoid it, you can make the thread to be undersized or mask it. However, to be on the safe side, you can do some samples to see the changes that will occur.

Hard Anodizing benefits

There are many benefits to carry out hard anodizing on aluminum parts instead of the standard anodizing process. Some of what the process will do the parts are:

1. Tolerance; hard coat will ensure that there is a uniform build-up on the contours of the part to ensure a close tolerance control. On parts that have unique shapes, hard coat anodizing becomes a necessity because it will enter all the corners.
2. Electrical properties; hard coats are good electrical insulators. They exhibit resistance to electricity like porcelain and glass.
3. Thermal Properties; hard anodizing coatings may not good for thermal conductivity, but it is excellent for thermal emissivity.
4. Color; hard coat offers many color varieties from colorless to being light brown if a pure aluminum is involved and the coating thickness gets as high as 25-75 ms.
5. Heat resistance; the hard coats can endure short-term exposures to a temperature of 2000 degrees C as a result of the coating's inert nature.
6. Increase in resistance to abrasion; one reason for hard coat anodizing is that it hardens the surface of the aluminum to resist abrasion easily.
7. Lightweight; this anodizing produces a coating that is light in weight.

8. Non-contamination; hard anodizing makes an aluminum part free from contamination, especially for medical instruments.

Some of the industries that utilize the benefits of hard anodizing are:

The aviation industry, Automotive, Home furnishing, Building and Architecture, Equipment, Marine Industry, Food manufacturing and Preparation, Sporting Products, Medical and Dental equipment, Law enforcement and Military.

Aluminum Anodizing at home

Are you aware that you can anodize aluminum in the comfort of your home? You don't have to wait till you set up an anodizing plant before you anodize aluminum especially when your project is just for a few parts. If you want to anodize your parts at home, you will have to handle it in four different stages.

Step One: Collecting your supplies.

Step Two: Cleaning the aluminum parts

Step Three: Setting up the anodizing bath

Step Four: Anodizing and dying.



Step One Collecting supplies

- Buy an aluminum metal part since anodizing works well with aluminum. Get small pieces so that the acid quantity for the submersion will not be much.
- Get a plastic tub that is very thick where you will submerge the metal. Remember, the plastic must be durable and very hard
- Buy a clothing dye or an anodizing dye so that you can dye the aluminum metal any color you want as you continue on the process.
- Get a degreaser product, one roll of aluminum wire, and two lead cathodes that are very long. You can get these items at your local hardware store.
- Buy a large quantity of baking soda, distilled water, and some rubber gloves.
- Get many gallons of sulfuric/battery acid, a power supply of 20 volts and lye. Visit the stores where they sell auto parts for battery acid. You can use a battery charger that is very large to supply constant power.

Step two: Cleaning the Aluminum Parts

- Wash the aluminum metal with water and soap
- Apply the degreaser with a clean towel to make it free of oil
- Then mix three tablespoons of lye in one gallon of your distilled water. Make use of a metal bowl or a plastic tub for this and allow the mixture to stay for three minutes, bring it out and rinse it thoroughly.

The reason for the lye is to make sure that if there is an anodizing coat on the metal surface, it will vanish and you will notice that water will pour off the aluminum surface easily. As you work with lye, make sure that you are wearing your rubber gloves. Also, avoid making use of those cups and spoons which you use in the kitchen to avoid toxic poisoning.

Step Three: Setting up the bath

After collecting your supplies and cleaning the parts, the next thing is to set up the bath by doing the following things:

- Bring your plastic tub and place it where there is adequate ventilation and away from other objects that can be affected during the process. Also, use a piece of thick cloth material or plywood and set around it to catch any spill. If you want to get the best anodizing results, do it when the room temperature is 21-22 degrees Celsius or 70 to 72 degrees Fahrenheit.
- Arrange your power supply on a material that is not flammable like concrete and be sure that the power will work and remain constant. Afterwards, connect a positive wire from the battery charger to a wire which you will string to the aluminum. Also, connect a negative wire of the battery to the aluminum wire which is connected to two lead cathodes. Apart from a battery charger, if you have a rectifier, it will still work.
- The best aluminum wire to use is 12-gauge wire and if you have it, tie one end of it to the part you want to anodize. Afterwards, connector wraps the wire the part in a hidden place. That area of the aluminum which you connected to the wire will not catch the anodizing coating. So make sure you wrap it very tight to achieve a consistent charge.
- Then, get a piece of wood that is very thin but wider than the plastic tub and wrap the aluminum wire round it. Don't forget that you must have extra wire after wrapping that will be extending towards the power supply. Test your wooden handle to be sure that the aluminum part will have a full submersion into the acid.
- Set one lead cathode on every side of the anodizing tank. Let the aluminum wire pass between your two cathodes and then, connect the two on a small plank. Attach the negative power to the wire and make sure that you separate the wire connecting both the lead cathode and the aluminum part to prevent them from touching.
- Pour a part of the distilled water and a part of the battery acid into the plastic tub. Measure the amount according to the size of the aluminum metal you are going to anodize. Avoid spillage at all cost and make sure that the water goes in first before you pour the acid. In case of any acid spillage, use baking soda to cover it. To be on a safe side, use a respirator or mask to cover your face before working with acid and put on a fan to provide adequate ventilation.
- Then connect the wire leading from the aluminum to the positive charge and connect the wire from your cathodes to the negative charge. Look around to ensure that there are no spills and that the power is well connected. Also, make sure that you have covered your skin very well

Step Four: Anodizing and Dying Aluminum Metal

- Turn on the power and increase it slowly. The right amount of power to use is 12 amps for each square foot of the aluminum material. The reason for the slow power increase is to prevent burning the aluminum wires.
- When you have increased it to the right amperage, keep it constant for at least 45 minutes. At this point, little oxidation bubbles will start forming on the aluminum surface. The color will also start to change to brown and then; it will turn yellow.
- During this anodizing process, mix your dye with part of the distilled water then heat the mixture to 100-140 degrees

Fahrenheit or 37-60 degrees Celsius.

- Turn the power off and bring out the aluminum part then rinse with the distilled water.
- Afterwards, place the part in your dye bath that is still warm and leaves it there for fifteen minutes.
- Still, on the process, use a hot plate and boil part of the distilled water. Bring out the aluminum from the bath and put in the hot plate of boiling water. Leave it for 30 minutes.
- Bring out the anodized aluminum and keep to dry.

Aluminum anodizing temperature control

If you want to have a better regulation on the anodizing tank temperature, you have to ensure that the temperature coming out from the anodizing tank should be higher than the one going into the anodizing tank. If there is a slow change in the temperature than the heat outlet exchanger, you may need a cascade system to ensure that the response is stable.

To better regulate the temperature, it is better to use two controllers and two sensors. The secondary loop will measure the level of temperature coming from the anodizing tank heat exchanger and also control the valve of the heat exchanger. The primary loop, on the other hand, will measure the temperature that is inside the tank or the one leaving the tank. Then, the output from the primary exchanger will provide the set point for the tanks' secondary exchanger.

One advantage of this arrangement is that it will isolate changes in the fluid pressure or changes in the temperature which the secondary loop is controlling. This temperature may be changing rapidly than the temperature of the primary loop. The secondary loop must be faster than the primary, and this is for quicker response. Tune the primary loop temperature to match the tank's slower response.

Aluminum anodizing process time

To determine the time it will take for different load size to anodize when it relates to current or voltage; you can do the following:

Let's say that you have a load of 35 sq. m. to anodize in a sulfuric acid solution of 195 to 205 g/l to 12 microns and the capacity of your rectifier is 5000 amps, using a voltage of 22 V.

To get a good estimate of how long it will take to process, use the "720 Rule" which says that it will take 720 amperage minutes per square ft. for 1ml of oxide. To apply this rule, divide 720 by the current density in amperage per square foot. Then you will know the time it will produce 1ml of oxide.

This rule works well if you are doing type 11 or sulfuric acid anodizing or type 111 hard coat anodizing. Also, if you want to know the time it will take to produce 1ml at an amperage of 24 v per square foot, divide 720 by 24 and you will get 30 minutes. Therefore, for 12 microns, the time will be 14.2 minutes.

Black Aluminum anodized finishes properties

Aluminum oxide is the second hardest substance you can get after diamonds. The anodic coating which is made up of aluminum oxide which forms under a controlled condition is very hard to be resistant to wear easily. Even if you rub aluminum oxide on a smooth surface facing the coating plane, it will remain resistant to wear.

You must also know that the anodic coating is brittle while the substrate is simply soft and as such, the coating will not be

resistant to any sharp impact. The aluminum oxide is inert and can suffer damages or dissolve if you use strong bases like sodium hydroxide or strong acids like nitric, hydrochloride, sulfuric, etc. on it for a long time.

That said, you should know the environment where you will use anodized aluminum plays an important role in whether it will last long or not. If you seal the finishing very well, it may withstand a variety of industrial and natural environments.

If we analyze the make-up of the anodized finishing, you will remember that the first layer of the coating is thin while the barrier layer thickness is 100-300 angstroms. The porous layer starting from the barrier layer is made of 98% of the whole coating. This layer is a thickness of 0.0001-0.002 inch or even more. Due to the porous nature of this third layer, it can withstand any substances like organic or inorganic, e.g., dyes of many colors. When you apply a dye on an anodic coating, it is the porous layer that absorbs it, and the more you apply on it, the deeper and long-lasting the color will be on the coating. Some of the black dyes are lightfast. When you go ahead with the sealing process after dyeing, it will give the anodizing coating a corrosion resistance capabilities. If you make sure that the anodic coating is as thick as adequate, has enough black dye absorbed into it, and then, also sealed properly, it will not leach out, and its corrosion resistance capacity will also be high. About the electrical properties, the anodic coating contains impressive dielectric properties. Sometimes, some types of coatings resist hundreds of volts to pass through it. However, it depends on the conditions.

Anodizing colors

After anodizing, you may decide to dye or leave it without dye. The terms used to describe these two situations are Class 1 for undyed or clear anodized part and Class 2 for dyed anodized aluminum. To dye an anodized layer, all you will do is to dip it into a tank containing hot dye after you finish anodizing it.

While dyeing, you can get many color shades, but the main one is usually black, then blue, red and then gold. However, the only type of anodizing that you can dye with many colors is type 11 of sulfuric acid anodizing. As for type 111 or hard coat anodizing, that one is always dark, and some people leave it like that or dye it with black.

You have to bear in mind that the color you will get from dyeing will not be the same thing as the one you get from powder coat or painting. It is not always easy to achieve color matching or color consistency in commercial anodizing. If you want to specify a color for your anodized part, you will make it broader like; blue, dark blue, or light blue. Don't start mentioning colors like deep sky blue, "electric indigo blue" etc

Don't forget that the color you will get from organic dyes will not be one hundred percent colorfast. Expect that these color will fade as time passes and if the parts are outdoors, the fading will be faster.

Another thing you should note is that the type of aluminum alloy you are dyeing will also affect the color you will get. E.g., Zinc alloys or High-copper alloys like 7075 or 2024 will give different colors than 6061 which is a lower copper alloy. Also, 6061 of the 3000&5000 series will be consistent while 7075 will show you a yellow tint if you did clear anodizing because it contains a high amount of zinc.

Anodizing color thickness

Using colorimeters to measure and match the color of anodic finishes is not accurate because if you use two brands, you might get different results. However, if you use a colorimeter to measure opaque and applied organic coatings, you will get an accurate reading but not in measuring the color of the anodized coating.

The reason for this variations is because the substrate has a metallic and reflective nature. Therefore, don't use a colorimeter to gauge colors for your anodized aluminum coatings. Instead, use visual inspection under a good light and color range

samples to measure your anodized color.

How to setup anodizing plant

Before deciding to set up an anodizing plant, you must first compare the cost of the plant and that of outsourcing your anodizing projects. If you are spending less on outsourcing, then you should continue, but if setting up a plant is more cost-effective, you should go ahead to set up an anodizing plant.



A complete anodizing plant has the following equipment:

- An anodizing tank
- A coloring tank
- Rinsing tanks
- Degreasing tank
- Etching tank
- DC Rectifier
- AC Rectifier
- Chemical Chiller
- Agitation Pump.

For the anodizing tank, ensure the following

- The tank will come in a high-grade polypropylene sheets
- The thickness will be within 10mm to 24mm
- The tanks will be fabricated with coatings that will not rust
- Let the tanks be insulated from outside, have Al 6063 pure grade Al Cathodes, bus bars, nut bolts fittings and Cooling Coils

When you have all the equipment ready, then decide whether you will set up a manual or automatic/semi-automatic anodizing plant.

For the automatic/semi-automatic plant setup, you can arrange the equipment like:

- Hot degreasing tank
- Water Rinse 1
- Water Rinse 2
- Nitric Dip
- Water Rinse 1
- Water Rinse 2
- Anodizing Tank
- Water Rinse 1
- Sealing Tank
- Oven/ Dryer

If it is a manual color plant setup, you can arrange it thus:

- Hot Degreasing Tank
- Water Rinse 1
- Water Rinse 2
- Nitric Dip
- Water Rinse 1
- Water Rinse 2
- Anodizing Tank
- Water Rinse 1
- Coloring Tank
- Sealing Tank
- Oven/Dryer

In an automatic or semi-automatic anodizing plant setup, there will be overhead cranes as well.

Anodizing plant cost

The cost of setting up an anodizing plant may vary depending on the type of anodizing you want to do. Don't forget, anodizing plant cost will also vary according to the anodizing needs you have. So before design, identify what you need and pass it on to the designers for more accurate costing.

Also, there are small, medium and large anodizing plant lines available in the industry. Most of the fabricated anodizing systems will normally look like in-line washing machines where all the necessary tanks will be available. Always decide on the size of the aluminum parts you will be anodizing to make an informed choice of anodizing plant.