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Anodizing, or **anodising** in British English, is an electrolytic passivation process used to increase the thickness of the natural oxide layer on the surface of metal parts. The process is called "anodizing" because the part to be treated forms the anode electrode of an electrical circuit. Anodizing increases corrosion resistance and wears resistance, and provides better adhesion for paint primers and glues than bare metal. Anodic films can also be used for a number of cosmetic effects, either with thick porous coatings that can absorb dyes or with thin transparent coatings that add interference effects to reflected light. Anodizing is also used to prevent galling of threaded components and to make dielectric films for electrolytic capacitors. Anodic films are most commonly applied to protect aluminum alloys, although processes also exist for titanium, zinc, magnesium, niobium, and tantalum. This process is not a useful treatment for iron or carbon steel because these metals exfoliate when oxidized; i.e. the iron oxide (also known as rust) flakes off, constantly exposing the underlying metal to corrosion.

Anodization changes the microscopic texture of the surface and changes the crystal structure of the metal near the surface. Thick coatings are normally porous, so a sealing process is often needed to achieve corrosion resistance. Anodized aluminum surfaces, for example, are harder than aluminum but have low to moderate wear resistance that can be improved with increasing thickness or by applying suitable sealing substances. Anodic films are generally much stronger and more adherent than most types of paint and metal plating, but also more brittle. This makes them less likely to crack and peel from aging and wear, but more susceptible to cracking from thermal stress.

HISTORY

Anodizing was first used on an industrial scale in 1923 to protect Duralumin seaplane parts from corrosion. This early chromic acid process was called the Bengough-Stuart process and was documented in British defence specification DEF STAN 03-24/3. It is still used today despite its legacy requirements for a complicated voltage cycle now known to be unnecessary. Variations of this process soon evolved, and the first sulfuric acid anodizing process was patented by Gower and O'Brien in 1927. Sulfuric acid soon became and remains the most common anodizing electrolyte.

Oxalic acid anodizing was first patented in Japan in 1923 and later widely used in Germany, particularly for architectural applications. Anodized aluminum extrusion was a popular architectural material in the 1960s and 1970s, but has since been displaced by cheaper plastics and powder coating. The phosphoric acid processes are the most recent major development, so far only used as pretreatments for adhesives or organic paints. A wide variety of proprietary and increasingly complex variations of all these anodizing processes continue to be developed by industry, so the growing trend in military and industrial standards is to classify by coating properties rather than by process chemistry.

ANODIZED ALUMINUM

Aluminum alloys are anodized to increase corrosion resistance, to increase surface hardness, and to allow dyeing (coloring), improved lubrication, or improved adhesion. The anodic layer is non-conductive.

When exposed to air at room temperature, or any other gas containing oxygen, pure aluminum self-passivates by forming a surface layer of amorphous aluminum oxide 2 to 3 nm thick, which provides very effective protection against corrosion. Aluminum alloys typically form a thicker oxide layer, 5-15 nm thick, but tend to be more susceptible to corrosion. Aluminum alloy parts are anodized to greatly increase the thickness of this layer for corrosion resistance. The corrosion resistance of aluminum alloys is significantly decreased by certain alloying elements or impurities: copper, iron, and silicon, so 2000, 4000, and 6000-series alloys tend to be most susceptible. Some aluminum aircraft parts, architectural materials, and consumer products are anodized. Anodized aluminum can be found on mp3 players, flashlights, cookware, cameras, sporting goods, window frames, roofs, in electrolytic capacitors, and on many other products both for corrosion

resistance and the ability to retain dye. Although anodizing only has moderate wear resistance, the deeper pores can better retain a lubricating film than a smooth surface would.

Anodized coatings have a much lower thermal conductivity and coefficient of linear expansion than aluminum. As a result, the coating will crack from thermal stress if exposed to temperatures above 80 °C. The coating can crack, but it will not peel. The melting point of aluminum oxide is 2050 °C, much higher than pure aluminum's 658 °C. (This can make welding more difficult.) In typical commercial aluminum anodization processes, the aluminum oxide is grown down into the surface and out from the surface by equal amounts. So anodizing will increase the part dimensions on each surface by half of the oxide thickness. For example a coating that is (2 μm) thick, will increase the part dimensions by (1 μm) per surface. If the part is anodized on all sides, then all linear dimensions will increase by the oxide thickness. Anodized aluminum surfaces are harder than aluminum but have low to moderate wear resistance, although this can be improved with thickness and sealing.

PROCESS

Preceding the anodization process, wrought alloys are cleaned in either a hot soak cleaner or in a solvent bath and may be etched in sodium hydroxide (normally with added sodium gluconate), ammonium bifluoride or brightened in a mix of acids. Cast alloys are normally best just cleaned due to the presence of intermetallic substances unless they are a high purity alloy such as LMO.

The anodized aluminum layer is grown by passing a direct current through an electrolytic solution, with the aluminum object serving as the anode (the positive electrode). The current releases hydrogen at the cathode (the negative electrode) and oxygen at the surface of the aluminum anode, creating a build-up of aluminum oxide. Alternating current and pulsed current is also possible but rarely used. The voltage required by various solutions may range from 1 to 300 V DC, although most fall in the range of 15 to 21 V. Higher voltages are typically required for thicker coatings formed in sulfuric and organic acid. The anodizing current varies with the area of aluminum being anodized, and typically ranges from 0.3 to 3 amperes of current per square decimeter (20 to 200 mA/in²).

Aluminum anodizing is usually performed in an acid solution which slowly dissolves the aluminum oxide. The acid action is balanced with the oxidation rate to form a coating with nanopores, 10-150 nm in diameter. These pores are what allow the electrolyte solution and current to reach the aluminum substrate and continue growing the coating to greater thickness beyond what is produced by aut passivation. However, these same pores will later permit air or water to reach the substrate and initiate corrosion if not sealed. They are often filled with colored dyes and/or corrosion inhibitors before sealing. Because the dye is only superficial, the underlying oxide may continue to provide corrosion protection even if minor wear and scratches may break through the dyed layer.

Conditions such as electrolyte concentration, acidity, solution temperature, and current must be controlled to allow the formation of a consistent oxide layer. Harder, thicker films tend to be produced by more dilute solutions at lower temperatures with higher voltages and currents. The film thickness can range from under 0.5 micrometers for bright decorative work up to 150 micrometers for architectural applications.

The most widely used anodizing specification, MIL-A-8625, defines three types of aluminum anodization. Type I is Chromic Acid Anodization, Type II is Sulfuric Acid Anodization and Type III is sulfuric acid hardcoat anodization. Other anodizing specifications include MIL-A-63576, AMS 2469, AMS 2470, AMS 2471, AMS 2472, AMS 2482, ASTM B580, ASTM D3933, ISO 10074 and BS 5599. AMS 2468 is obsolete. None of these specifications define a detailed process or chemistry, but rather a set of tests and quality assurance measures which the anodized product must meet. BS 1615 provides guidance in the selection of alloys for anodizing. For British defense work, detailed chromic and sulfuric anodizing processes are described by DEF STAN 03-24/3 and DEF STAN 03-25/3 respectively.

Chromic acid anodizing (Type I)

The oldest anodizing process uses chromic acid. It is widely known as the Bengough-Stuart process. In North America it is known as Type I because it is so designated by the MIL-A-8625 standard, but it is also covered by AMS 2470 and MIL-A-8625 Type IB. In the UK it is normally specified as Def Stan 03/24 and used in areas that are prone to come into contact with propellants etc. There are also Boeing and Airbus standards. Chromic acid produces thinner, 0.5 µm to 18 µm (0.00002" to 0.0007") more opaque films that are softer, ductile, and to a degree self-healing. They are harder to dye and may be applied as a pretreatment before painting. The method of film formation is different from using sulfuric acid in that the voltage is ramped up through the process cycle.

Sulfuric acid anodizing (Type II & III)

Sulfuric acid is the most widely used solution to produce anodized coating. Coatings of moderate thickness 1.8 µm to 25 µm (0.00007" to 0.001") are known as Type II in North America, as named by MIL-A-8625, while coatings thicker than 25 µm (0.001") are known as Type III, hardcoat, hard anodizing, or engineered anodizing. Very thin coatings similar to those produced by chromic anodizing are known as Type IIB. Thick coatings require more process control, and are produced in a refrigerated tank near the freezing point of water with higher voltages than the thinner coatings. Hard anodizing can be made between 25 and 150 µm (0.001" to 0.006") thick. Anodizing thickness increases wear resistance, corrosion resistance, ability to retain lubricants and PTFE coatings, and electrical and thermal insulation. Standards for thin (Soft/Standard) sulfuric anodizing are given by MIL-A-8625 Types II and IIB, AMS 2471 (undyed), and AMS 2472 (dyed), BS EN ISO 12373/1 (decorative), BS EN 3987 (Architectural) . Standards for thick sulfuric anodizing are given by MIL-A-8625 Type III, AMS 2469, BS 5599, BS EN 2536 and the obsolete AMS 2468 and DEF STAN 03-26/1.

Organic acid anodizing

Anodizing can produce yellowish integral colors without dyes if it is carried out in weak acids with high voltages, high current densities, and strong refrigeration. Shades of color are restricted to a range which includes pale yellow, gold, deep bronze, brown, grey, and black. Some advanced variations can produce a white coating with 80% reflectivity. The shade of color produced is sensitive to variations in the metallurgy of the underlying alloy and cannot be reproduced consistently.

Anodization in some organic acids, for example Malic Acid, can enter a 'runaway' situation, in which the current drives the acid to attack the aluminum far more aggressively than normal, resulting in huge pits and scarring. Also, if the current or voltage is driven too high, 'burning' can set in; in this case the supplies act as if nearly shorted and large, uneven and amorphous black regions develop.

Integral color anodizing is generally done with organic acids, but the same effect has been produced in laboratory with very dilute sulfuric acid. Integral color anodizing was originally performed with oxalic acid, but sulfonated aromatic compounds containing oxygen, particularly sulfosalicylic acid, have been more common since the 1960s. Thicknesses up to 50µm can be achieved. Organic acid anodizing is called Type IC by MIL-A-8625.

This information is derived from Wikipedia and to read more about it [CLICK HERE](#).