ESTAL
European association for Surface Treatment on Aluminium

Aluminium Anodising

Anodising is a simple electrochemical process developed in the 20th century that forms a protective coating of aluminium oxide on the surface of the aluminium.

Purpose of anodising

Although aluminium resists corrosion sufficiently that it maintains its structural integrity when exposed to the atmosphere, superficial corrosion can take place that mars its appearance. The purpose of anodising is to produce a thick surface layer of aluminium oxide that protects the aluminium from any corrosion and provides an inert surface that maintains its initial appearance over very many years.

Aluminium alloys are anodized to increase resistance to corrosion and wear (abrasion and erosion) and also to allow colouring, improved lubrication, or improved adhesion. The anodic layer is non-conductive.

Pre-treatment

The anodized coating is transparent so the appearance of the underlying metal can be seen. Thus, anodizing is compatible with the natural appearance of the aluminium. Consequently, pre-treatment before anodizing is very important as it determines the visual appeal of the final anodized product. The aluminium surface can be treated by any of a range of mechanical and chemical methods including shot blasting, linishing, brightening and etching. Etching in a solution based on sodium hydroxide is often used to produce a satin matt, metallic finish.

The anodising process

The process is called *anodising* because the part to be treated forms the anode electrode of an electrical circuit. A **coating of aluminium oxide** is grown from the aluminium by passing an electrical current through an acid electrolyte bath in which the aluminium is immersed.

1. Oxide layer

The **anodic film** itself grows at the aluminium / aluminium oxide interface by the continuous formation and dissolution of a very thin layer of oxide; this is the so-called barrier layer and its thickness is a function of the process voltage. A thick, porous layer forms on top of the barrier layer making up the rest of the coating. Its thickness depends on the amount of electricity passed through the circuit

The coating is integral to the metal and cannot peel or flake. The structure of the coating consists of many, very small pores, which are filled with inert material during a sealing process.

Practical experience and weathering tests have shown that the service lifetime of anodized aluminium exposed to the atmosphere depends on the thickness of the coating. In comparison, the effect of the alloy used in such applications is negligible.

In general film thicknesses of 10 to 30 micrometres are used for outdoor applications. In engineering applications, especially for hard anodising, the usual range is 30 to 250 µm.

2. Colouring

Anodic films can be used for a number of decorative effects, either with thick porous coatings that can take up colorants or with thin transparent coatings that add interference effects to reflected light.

The most common anodising processes, for example sulfuric acid on aluminium, produce a porous surface which can accept dyes easily. The colours produced tend to vary according to the base alloy. However, lighter colors may be difficult to produce on certain alloys. Certain organic dyes have acceptable UV resistance when absorbed into anodic films.

Alternatively, metal (usually tin) can be electrolytically deposited at the base of the pores of the anodic coating to provide colors that are fully lightfast. The colours are produced by light scattering and absorption and range from pale champagne to black. Bronze shades are commonly used for architectural use. Grey and grey/blue colours can also be produced using this technology.

Alternatively the colour may be produced integral to the film. This is done during the anodising process using organic acids mixed with the sulfuric electrolyte and, often, special alloys.

3. Sealing

Acidic anodising solutions produce pores in the anodized coating. These pores can retain colorants, and are usually sealed to prevent cosmetic deterioration of the coating during weathering and to prevent loss of any colorants. Long immersion in boiling-hot deionized water or steam is the simplest sealing process where the pores are filled by hydrated aluminium oxide.

Cold sealing, where the pores are closed by impregnation of a sealant, usually nickel hydroxide, in a room-temperature bath, is popular due to energy savings.

Advantages of Anodising

Many metals are structurally weakened by oxidation processes including corrosion, but not aluminium. Aluminium can actually be made more durable through the anodising process, The oxidized aluminium forms a coating as it replaces the original aluminium on the surface. The result is an extremely hard and wear-resistant substance on the surface of the aluminium.

Anodized coatings on aluminium can be made nearly as hard as diamond with the right anodising process. Many modern buildings use anodized aluminium in places where the metal framework is exposed to the elements. The process of anodising provides a naturally protective finish.

Applications for anodized aluminium

Because of its durability, anodized aluminium is not only used in architectural applications, but also in a number of other applications. The automobile industry relies on anodized aluminium for trims, hub caps, roof bars and protective housings for exposed parts. Furniture designers often use anodized aluminium as the framework for outdoor pieces as well as the base metal for lamps and other decorative items. Modern home appliances and computer systems may utilize anodized aluminium as protective housings.

Although the anodic film is translucent, it does reflect some light from its outer surface. The double reflection from the surface of the metal and the surface of the film gives the material a “lively” appearance that is particularly attractive to designers.

Anodized aluminium may not be appropriate for all applications because of its non-conductive nature.

History of Anodising and the various processes

Anodising was first used on an industrial scale in 1923 and was a **chromic acid**–based process. Chromic acid anodising is still used today in specialised applications (e.g. high strength aluminium alloys for aerospace)

Variations of this process soon evolved, and the first **sulfuric acid anodising** process was patented in 1927. Sulfuric acid soon became and remains the most common anodising electrolyte. It comprises anything from heavy duty black dyed coatings for high-tech instruments to cheap objects. It also includes architectural anodising primarily for protecting aluminium window frames etc from the elements. The natural colour of these is light grey; other colours are achieved by introducing colorants into the film. Anodized aluminium was first used in architectural applications in the 1930s; some of those buildings still exist and where proper cleaning has been carried out, the anodized aluminium looks as good as new.

Hard Anodising is a branch of sulphuric acid anodising where process conditions have been pushed to achieve significantly harder, thicker, denser films. Applications involve resistance to wear, corrosion, temperature effects etc. Lubricants can be introduced in the pores of the film for better performance of moving parts.

Oxalic acid anodising was first patented in Japan in 1923 and later widely used in Germany, particularly for architectural applications.

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 anodising processes continue to be developed by industry.

Anodising can also be performed in **borate or tartrate baths** in which aluminium oxide is insoluble. In these processes, the coating growth stops when the part is fully covered, and the thickness is linearly related to the voltage applied. These coatings are free of poresand are widely used to make electrolytic capacitors.

Environmental impact

Anodising is one of the more environmentally friendly metal finishing processes. In general, the by-products contain only small amounts of heavy metals. The most common anodising effluents, aluminium hydroxide and aluminium sulfate, can be recycled or used by industrial wastewater treatment systems.

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