



Adhesive Selection for Bonding Anodized Aluminum Surfaces

White Paper



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Adhesive Selection for Bonding Anodized Aluminum Surfaces



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Anodizing aluminum is an important electrochemical industrial process for creating a cosmetic and/or protective layer on aluminum. In this white paper we will discuss how the anodizing process works, specifications covering the process and selection of adhesives for anodized surfaces.

What is Anodizing?

Anodizing is an electrochemical process which deposits a protective layer on the surface of the aluminum for reasons of corrosion protection, aesthetic coloring, wear protection.

The basic process of anodizing is: aluminum is cleaned and added to a tank of acid (phosphoric, chromic, sulfuric, etc.), an electrical current is passed through the part/sheet/extrusion which deposits an aluminum oxide layer on the surface of the aluminum.

The surface of this oxide layer is porous. Figure 1 shows the basic structure of the oxide layer formed on the surface of the aluminum and Figure 2 shows an electron microscope image of the pores formed in the anodizing process.

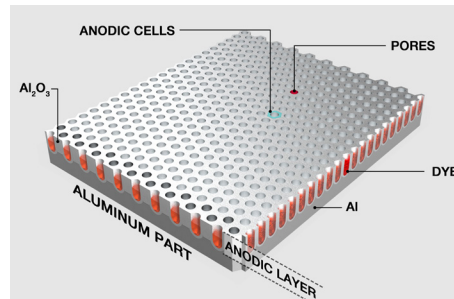


Figure 1: Basic structure of oxide layer

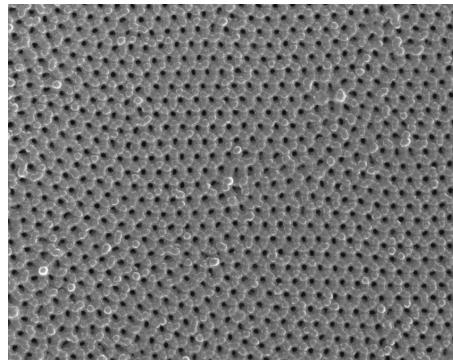


Figure 2: Pores formed in anodizing process

Specifications for Anodizing

Specifications govern how the anodizing process is performed and the most common specification for anodizing is Mil Spec-A-8625F. The military specification (Mil-Spec) breaks down anodizing into three Types, based on the acid bath used and coating thickness along with two classes. The Type I anodizing is chromic acid anodizing and is far less common now due

to environmental concerns of chromium. Type I is further broken down into Type IA and Type IB, where Type IB is used for 7000 series aluminum alloys at low voltage bath. Both Type IA and IB produce coating thicknesses of 0.5μ - 7.6μ (microns).

Type II anodizing is sulfuric acid anodizing. By far the most common process used, sulfuric acid anodizing produces a layer thickness of 1.8μ - 25.4μ (microns). Architectural finishes are Type II process, but are not covered by the Mil-Spec. Rather, the Aluminum Association produces a series of finishing specifications which cover architectural finishes. Example would be A-21, a decorative finish, sulfuric acid anodized (Type II) which has a clear coating applied after any colored finishes.

Type III anodizing is often referred to as black, hardcoat anodizing. Type III is a sulfuric acid process and creates a much thicker oxide layer - 12.7μ - 115μ (microns). Hardcoating is often used as a protective wear layer for aluminum parts.

The Class annotated after the Type of anodized refers to dyeing. Under the Mil-Spec, Class 1 is undyed or clear; Class 2 is dyed (colored).

The aviation industry has a long experience using and specifying anodized finishes for bonding aircraft structures and different specifications have been developed. Examples of these other processes include thin-film anodizing developed by Boeing, which is a boric/sulfuric acid process and is covered by AMS 2470. Phosphoric

acid anodizing is used for pre-paint and pre-bonding surface preparation. It does not offer significant corrosion protection, hence the reason it is used prior to some other surface coating or process. This is covered by ASTM D 3933 and Silorsky's SS8482.

Finishing Anodized Surfaces

Once the porous layer of oxide is formed, the anodized layer can be colored (inorganic, organic dyes, metal salts) which fills the pores and then the pores are sealed (chemicals, steam, hot water, chemical coatings). Ultimately, this surface (sealed pores and colorants or coatings) is the surface which adhesive needs to adhere. Once color is applied and sealed, the anodized surface is complete. Note that this layer of aluminum oxide has a lower adhesion to base aluminum and is a weaker bond than some adhesives used in bonding.

It is important to understand that the adhesive bond is only as good as the weakest link in this “chain” of bonded surfaces – the strength of the aluminum oxide’s bond to the base aluminum – the dye’s and/or coating’s adhesion to the aluminum oxide pores – and the strength of the adhesive bond to

the anodized surface (sealed pores, chemical used to seal the pores, dyes, chemical coating over the pores). Performing bond testing on an anodized surface is used to understand how the various layers and adhesives work together and where failure will occur when loading is applied.

Bonding to Anodized Surfaces

Adhesives can bond quite well to anodized surfaces due to the nature of pores created in the process. Adhesives which can wet out (spread) on the surface generally can flow into the pores and create an addition mechanical keying as they cure into the rough surface. Most steam or hot water sealed and unsealed, undyed (colored) anodized finishes provide good bonding surfaces. Clear finishes, colored, dyed finishes should be checked for adhesive wet out and, most importantly, bond strength to the finish on the surface.

A good practice is to have the adhesive supplier conduct testing on the specified, representative anodized surface. Testing should include tests for adhesion to the anodized surface and what effects environmental conditions have on the adhesive bond (if any).

The anodizing process can create a wide array of different bonding surfaces as outlined previously. It is best if you understand how the adhesive performs on the surface specified for your unique process or assembly.

General Guidelines for Selecting Adhesives for Anodized Surfaces

A good first step when bonding is to have the anodizer perform a final step of hot water cleaning/sealing of the surface. Many types of chemical sealers use surfactants to reduce smut buildup during the anodizing process and these sealers can be an impediment to good bonds (surfactants are an important component of soaps).

Epoxies and acrylic adhesives designed for metal bonding are good first choices for bonding anodized surfaces. Polyurethanes and epoxies are better choices for anodized surfaces where a clear coating had been applied to seal in organic/inorganic and metallic dyes. Be sure to ask what kind of coating is being applied (chemical wash, epoxy coating, polyurethane coating, etc.) and have the adhesive supplier perform adhesion testing to this coated surface.

Epoxy Adhesive Performance Data

LORD® Epoxy Adhesives on 2024T3 Aluminum – Phosphoric Acid Anodized, Sodium dichromate wash per ASTM D3933

Adhesive	Test Conditions (psi)						
	-40°C	21°C	82°C	7-day Water Soak	7-day De-Ice Soak	7-day Hydraulic Soak	7-day JP4 Soak
LORD 309 (1:1 ratio)	3372	4239	1156	3163	3961	3724	4110
LORD 310 (1:1 ratio)	2263	3090	1096	2943	3034	3048	3017
LORD 3135 (1:1 ratio)	1647	2207	287	2027	1998	2360	2346

All Lap Shear samples used 5 mil (0.127 mm) bondline thickness.
All data per Lap Shear Testing, ASTM D1002, 0.05 in/min crosshead speed.
LORD 309 and LORD 310 specimens used a cure cycle of 121 °C for 45 minutes plus 180 °C for 45 minutes.
LORD 3135 used a cure cycle of 121 °C for 60 minutes.

Types I and II have a plethora of dyes/coatings/sealing techniques used in the anodizing process. In general, clear, uncoated, undyed surfaces are best for bonding.

Type III (hardcoat/ black anodized) specify hot, deionized water seal in lieu of nickel acetate sealing or use a sodium hydroxide etching of the final surface.

Resources for Further Reading on Anodizing

- Aluminum Anodizers Council - www.anodizing.org
- Aluminum Association – www.aluminum.org
- Aluminum Extruders Council – www.aec.org

Acrylic Adhesive Performance Data

LORD® 850 Acrylic Adhesive on 204T3 Aluminum – Phosphoric Acid Anodized, Sodium dichromate wash per ASTM D3933 or Type II, Class 1 anodized per Mil- A-8625

LORD 850/25GB			Lap Shear Strength (psi/MPa)						
Standard	Acid	Alloy	-40°C	21°C	65°C	Post Baked	500 hrs SS*	1000 hrs SS*	Temp/ Humidity Cycle**
ASTM D3933	Phosphoric	2024T3	3661/25.2	2678/18.5	1133/7.8	2482/17.1	2300/15.9	2363/16.3	2366/16.3
Mil-A-8625	Sulfuric	5005H34	2753/19.0	2187/15.1	1279/8.8	2382/16.4	2312/15.9	2220/15.3	2334/16.1

All data per Lap Shear Testing, ASTM D1002, 0.05 in/min crosshead speed.

LORD 850/25GB			T-Peel (pli)		
Standard	Acid	Alloy	Room Temperature	1000 hrs SS*	Temp/Humidity Cycle**
ASTM D3933	Phosphoric	2024T3	39.2	44	47.5
Mil-A-8625	Sulfuric	5005H34	39.1	42.7	43.3

*500 hrs SS and 1000 hrs SS – samples exposed to salt fog per ASTM B117.

**Temp/ Humidity Cycle – 120 cycles. Each cycle = 2 hours -40°C/ 0% RH, 1 °C/ min ramp: 85°C/ 85% RH 2 hours. Total of 720 hours.



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