LORIN

TRANSPORTATION GUIDE TO ANODIZED ALUMINUM

ACCELERATED DESIGN

Transportation Guide to Anodized Aluminum

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Understanding the challenges

At Lorin, we understand the challenges you face. You are asked to create beautiful products, made from high quality materials that deliver a consistent look and finish. These products also must be durable, able to be formed into a variety of shapes for different parts, be strong, yet lightweight to help preserve fuel, and if possible these materials should be made from sustainable materials made by sustainable processes.

Don't worry, at Lorin, we have you covered!

Section 1A: See It, Dream It, Believe It

Luxury performance no longer has to have a luxury price tag. No matter what signature look you are trying to create for your transportation product designs, anodized aluminum can accelerate it.

If you want to capitalize on the desire for products that have a natural metals look, then Lorin can provide a myriad of natural metal looks, without adding the extra weight and hefty price tag that comes along with those metals.

Perhaps the most important attribute of anodized aluminum is its beauty. The anodic layer of aluminum oxide is a translucent crystalline structure that enhances the natural metallic beauty of the aluminum beneath. This three dimensional sapphire crystalline structure reflects and refracts light in unique ways helping the material come alive in a way that paint cannot match.

Paint, as a coating applied to metal, is more one dimensional and flat in appearance. It simply cannot reproduce the natural metallic look of real aluminum. Conversely, paint covers up the natural metal below.

Paint **Anodized**

Painted aluminum is not metallic to the touch, and cannot be distinguished from any other painted material, resulting in a lack of natural metal feel and visual effect.

1B: Lots of Color and Finish Options

Lorin has the ability to create custom colors, as well as match almost any color that can be imagined, especially for interior finishes. In addition, these colors can be applied to finishes that are brushed, embossed, bright or matte.

With Lorin's continuous coil process, every square inch or millimeter of the entire coil spends the same amount of time in each part of the process. This allows Lorin to create an unmatched level of consistency, assuring that the colors and finishes look the same throughout all of the coils produced. Lorin carefully controls, measures, and records the color so it can be repeated on subsequent orders.

Lorin offers a wide variety of UV stable colors that can mirror or match natural metal looks, including stainless steel, brass, gold, zinc, pewter, bronze, copper, and muntz. Some of these metal looks are also available in pre-patina or antique versions.

While paint can offer many colors, like any organic coating, it will fade because it is simply an applied coating, using pigments or dyes that have limited life in terms of color-fastness due to UV rays breaking down the chemicals within the coating.

The cost of clear anodized, per square foot or meter, is comparable to a high quality pvdf paint. For a true bronze, copper, or zinc look, anodized aluminum may be a little more expensive than paint, but it does not appear flat like paint, and is much more affordable than the natural metals it is replacing.

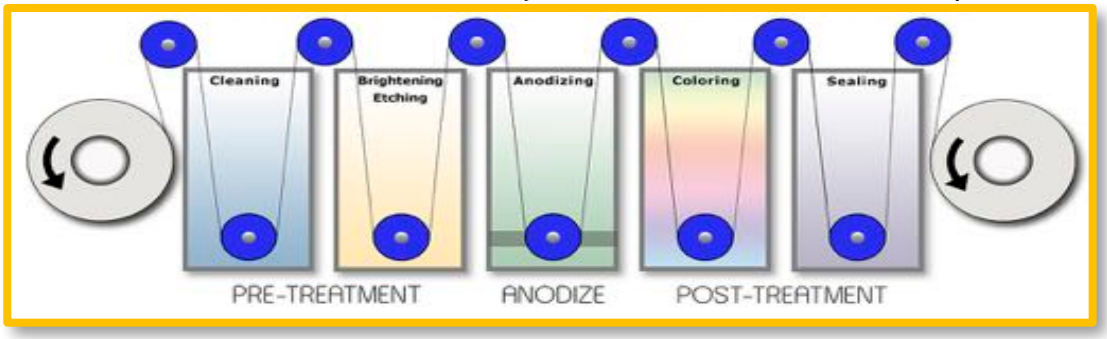
Section 2: Performance, Durability and Functionality

2A: How We Do It

Coil anodizing is an electrochemical process, not an applied coating. The end result is nothing short of scientific magic with nearly limitless design possibilities and coil-loads of efficiencies. To let you in on the secret, here's how it works.

THE COIL ANODIZING PROCESS

Coiled raw aluminum is unwound and pulled through a series of tanks, each playing a vital role where we clean, anodize, color, and seal the aluminum before we rewind the coil. Afterwards we can cut and deliver ready-to-fabricate coils all in one stop.



Step 1: Cleaning

Raw aluminum is covered in grit and grime. The cleaning tank is exactly that: ensuring all contaminants are washed away so the final surface is flawless.

Step 2: Pre-treatment

Depending on the desired finish, the pre-treatment wash could be chemically:

- Etched, removing a thin surface layer creating a matte look.

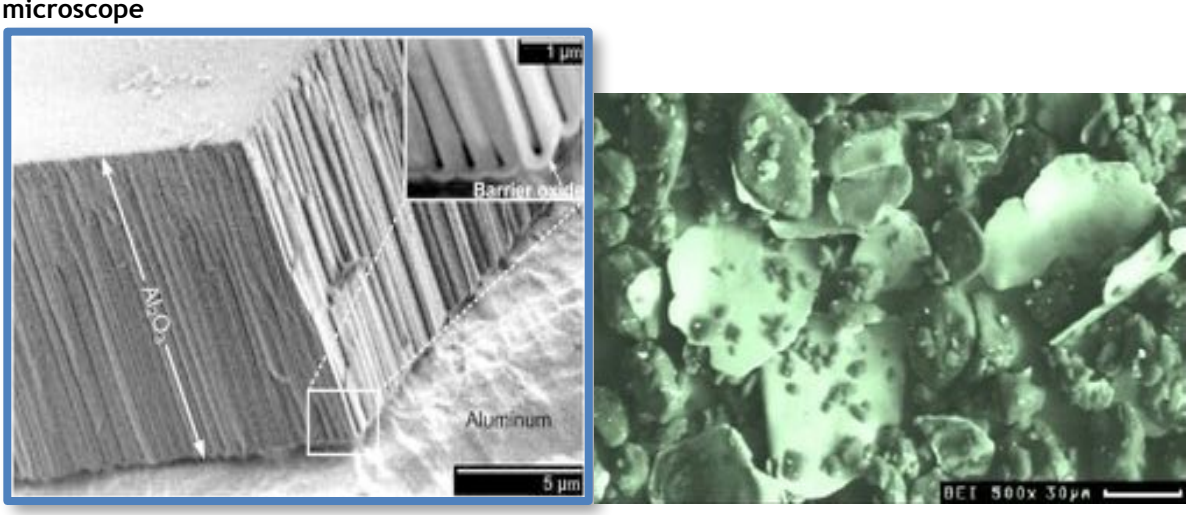
- Brightened to smooth the surface and heighten its reflectiveness.
- Electropolished as a more eco-friendly alternative for a chrome aesthetic.

Step 3: Anodizing
Using sulfuric acid electrolyte, an electrical current chemically builds grows an anodic film from the aluminum surface. The new layer is hard and porous—perfect for coloring.

Step 4: Coloring
For vibrant colors, but not necessarily UV stable colors, dyestuffs of any hue are absorbed directly into the anodic layer. For a UV stable metallic look, metal salts are electrolytically deposited. Both leave unmatched color intensities you never thought possible.

Step 5: Sealing
Here we close the pores, lock in the colors, and create a tough, resilient, finished surface.

Anodized surface under an electron microscope **Paint surface under an electron microscope**



2B: Lightweighting

We understand that in automotive, there is pressure with the formal C.A.F.E. standards to provide lightweight, but strong materials. We also understand that the underlying reasons for the standards make good business sense for all transportation markets – improve efficiency and reduce fuel consumption. Aluminum's high strength to weight ratio is no secret to the transportation market. After all, aluminum honeycomb panels have been used for aircraft wings, aircraft and rail car interior walls and floors for decades. Lorin has solutions to improve bonding of aluminum to various substrates, including honeycomb panels. See image below for honeycomb panel construction.

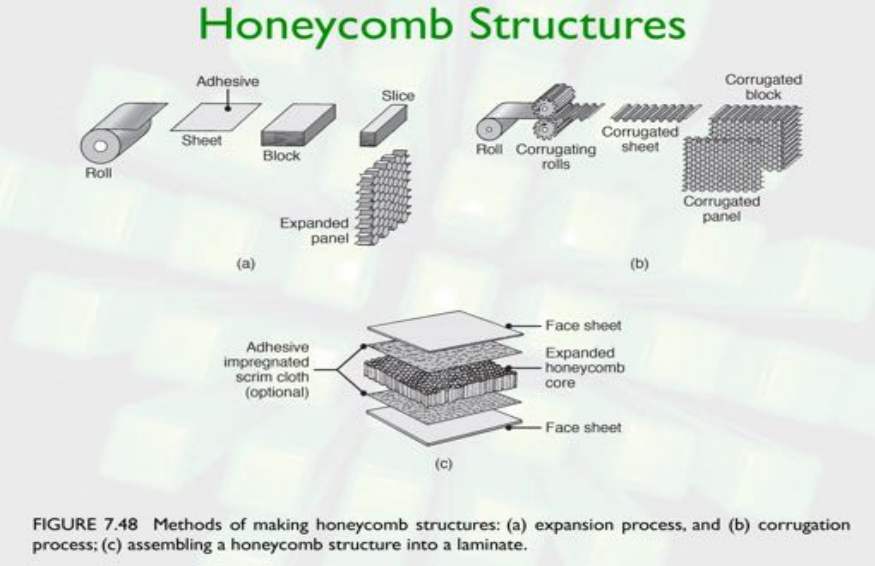
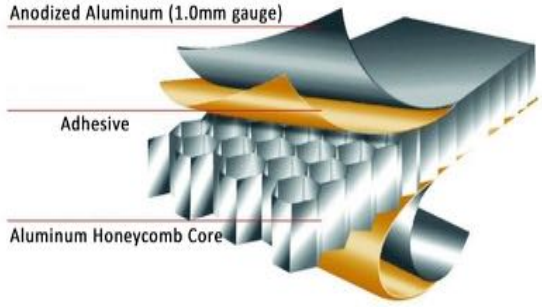
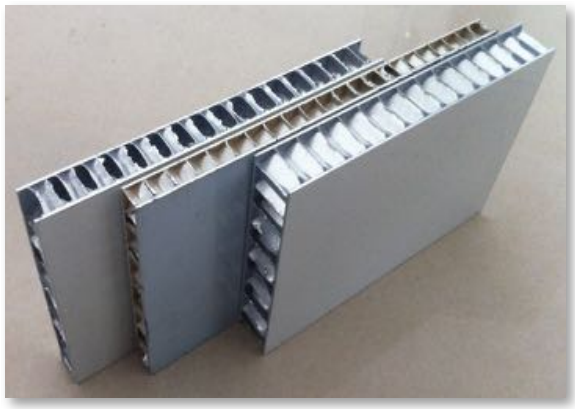
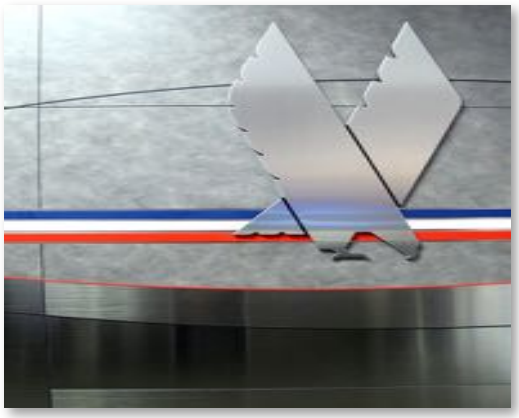


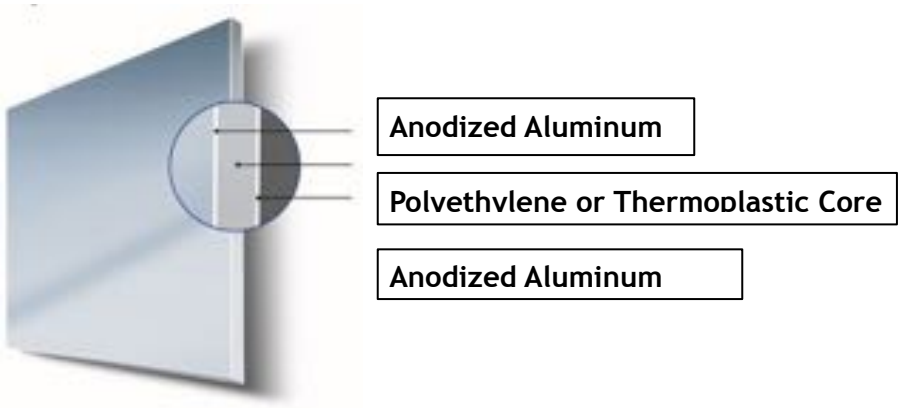
FIGURE 7.48 Methods of making honeycomb structures: (a) expansion process, and (b) corrugation process; (c) assembling a honeycomb structure into a laminate.





Laminating





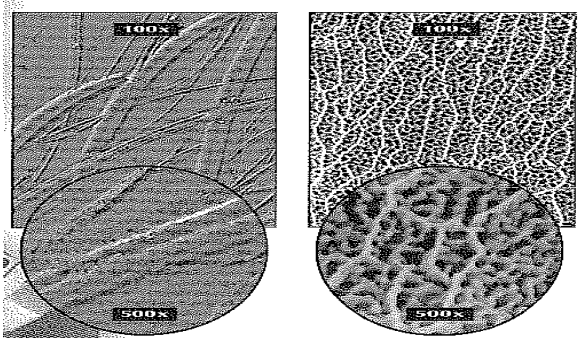
2C: Adhesion Enhancing Solutions

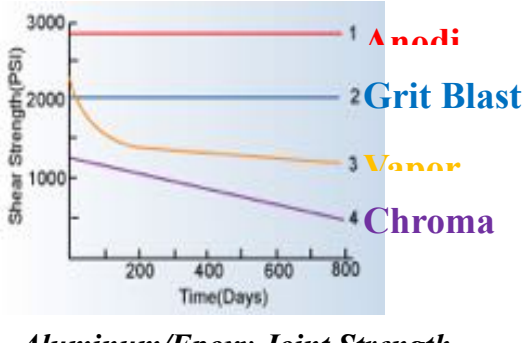
No matter what surface anodized aluminum needs to adhere to, Lorin has a patented solution for that. If you paint, bond, screen print, powder coat or virtually any other type of coating or bonding with aluminum or anodized aluminum, you need Lorin.

When you need an adhesive promoting surface on both sides, (like for dashboards, control panels or floors), AnoGrip® ensures no delamination. When you want the beauty of anodized aluminum on one side and some laminated on the other, Adhere® enables gluing without primer.

Typical "scuffed" surface of painted aluminum taken with electron microscope. Note the minimal ridges and valleys formed by pieces of grit.

AnoGrip on surface of raw aluminum taken with electron microscope. Note extensive number of surfaces to which coatings can attach.



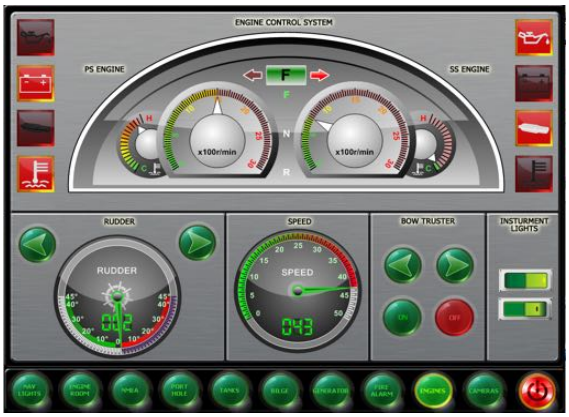


Aluminum/Epoxy Joint Strength

AnoGrip® is a special anodizing process applied to functional coil-anodized aluminum leaving both sides of the aluminum sheet with millions of microscopic pores that lock in paints, powder coats, adhesives and more - creating a permanent molecular bond.

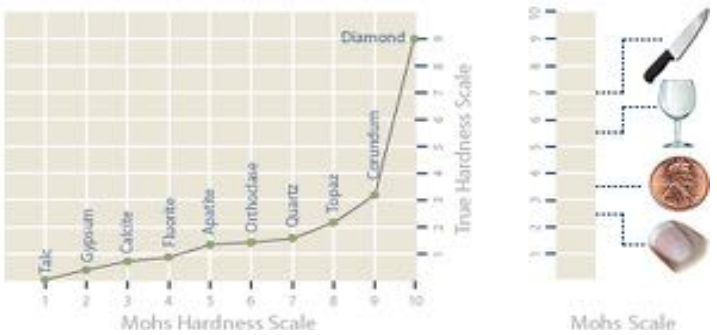
Adhere® is a post-anodizing process applied to the backside of decorative coil-anodized aluminum that leaves the back of the sheet with an adhesive friendly, open pore, no primer needed structure allowing for quick, solid attachment - perfect for anything like resin soaked papers, MDF board, composite or honeycomb panels, or foam insulated or various sound deadening materials.

2D: Applications for Adhere® and AnoGrip®:



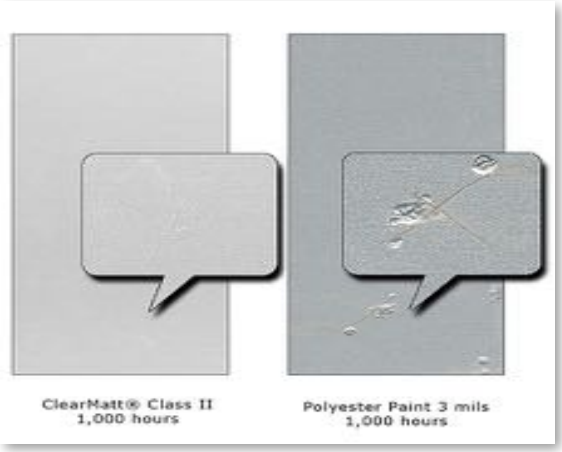
2E: Unmatched Abrasion/Corrosion Resistance

Aluminum Oxide is part of the Corundum family of gemstones, like a sapphire, and is second only to diamonds in terms of hardness. The hardness of the anodic layer makes it very abrasion resistant, outperforming paint in Tabor abrasion and pencil hardness tests, which means a more durable product with a better Return on Investment.



The sapphire hardness of aluminum oxide protects and preserves the aluminum surface from corrosion in harsh weather environments, including coastal areas. Salt spray is ph neutral, so it has little impact on the anodic layer, and the anodic layer's hardness helps keep the

aluminum beneath from being damaged. This is why anodized aluminum is often used for marine parts.



ASTM B 117 Resistance to Salt Spray Exposure

AAMA 611-12 Architectural Anodized Standards

Because paint is a coating that is either rolled or sprayed onto the base aluminum, it relies on the surface tension it creates with the metal, or a primer, for adhesion. This surface tension can break down over time, causing the paint to lose adhesion, leading to chalking, chipping, flaking and peeling. This loss of adhesion can creep over time, causing more and more of the surface area to lose its paint.

Anodized will not chip, flake, peel or rust.

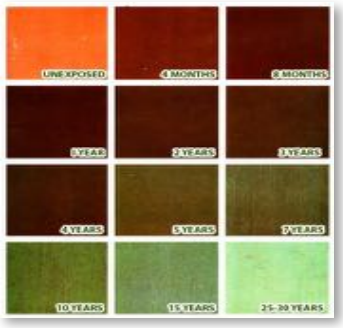
If the anodic layer is breached all the way to the raw aluminum underneath, the aluminum will self-heal by creating its own protective oxide layer, ensuring that the damage will not creep beyond the initial damage point. This mitigates the need for costly repairs.

2F: Compared to other metals

Unlike copper, zinc, steel or brass, anodized aluminum will not patina, rust or succumb to the elements.

Lorin Antique Copper ColorIn – UV Stable

Natural Copper patinas over time



2G: Easy to Maintain

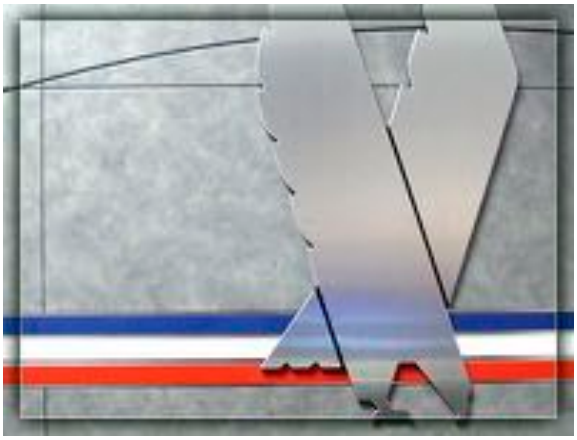
The anodic layer is easy and safe to clean without special chemicals, which results in low maintenance costs. Paint can easily be scratched or chipped. Damage to the painted surface can lead to corrosion under the paint, causing the damage to "creep" over time. This results in painted metal having higher maintenance costs than anodized aluminum.

Section 3A: Formability

Any material that is bent or stretched will have micro-fractures along the bend, also known as crazing, because nothing is infinitely flexible, including paint. Crazing occurs because the outer side of the bend is stretched more than the inner side, and appears as a frosted effect. (See our white paper on Forming and Crazing). While a bent anodized surface may exhibit visible crazing, it is often naturally obscured because of the way light reflects off a bend to create a brighter, frosted type effect. In the hands of a skilled former, bent anodized parts can be made to look great whether roll-formed, formed in a break press, aluminum composite panels, honeycomb panels, stamped, or perforated.

Roll Forming Operation

Stamping



Laminating

Perforating

Brake Press

3B: Product Applications

AUTOMOTIVE
Dashboard & Controls
Door Handles
Emblem/Name Plates
Light Reflectors
Exterior Bright Trim
Wheel Covers
and many more

RAIL CARS
Subway Rail Panels
Ceiling Systems
Seating Framework
Light Housings
Floor Systems
Lightweight Mirrors
and many more

RECREATIONAL
Interior Trim Decor
Structural Components
Ceiling Systems
Dashboard & Controls
Stove Fronts
Refrigerator Fronts
and many more

COMMERCIAL
Aircraft Interiors
Commercial Trailers
Trailer Rear Doors
Utility Trailers
Trailer Interiors
Bus Interior Panels
and many more

Speaker grills

Car Emblems

Automotive Trim

C.H.I.M.S.L. example

Section 4: Sustainability

Anodized aluminum remains pure aluminum, with nothing that can create VOCs or off-gassing. There are no red list items in anodized aluminum, and it meets ROHS standards.

Although it may not be directly important, a further sign of the safety of anodized aluminum is that clear anodized aluminum is approved for primary food contact by the National Sanitary Foundation, and all colored anodized aluminum is approved for splash zone food areas. Additionally, aluminum oxide is often used in products such as baking soda and antiperspirant. What this means to you is an added level of assurance about the safety of anodized aluminum for use in products you design and engineer.

The anodizing process is environmentally friendly, creating no hazardous waste. The process uses high and low ph chemicals that combine to create an environmentally neutral by-product. Lorin actually extracts and recycles most of the chemicals used in its process. Lorin's waste water treatment facility returns water to the city, with no additional treatment required. Additionally, Lorin has its own clean energy natural gas powered co-generation power plant to be more environmentally responsible, and to lessen the city's power burden during peak demand hours.

Aluminum, even when anodized, is one of the only metals that is 100% recyclable, and can be repeatedly recycled through simple re-melting.

Paint contains chemicals that include VOC's, which are dangerous to humans, animals, and the environment. Additionally, painted aluminum requires further processing before it can be recycled. Chrome is a known carcinogen and is an environmental disaster to produce. Stainless steel uses chromium as part of its formulation and neither can be completely recycled.

Section 5: Summary

With functional benefits of a high strength-to-weight ratio and superior durability, and the aesthetic benefits of a beautiful natural metal look in a variety of colors, anodized aluminum is uniquely suited to bring innovative transportation designs to life.
If you want a material that is very durable, offers a natural metal look, is available in many colors and finishes, is environmentally responsible, can be formed into many shapes or parts, offers a great ROI, and is truly beautiful in unique ways that paint and other coatings cannot match, then Lorin's anodized aluminum is a product that you need to try. We would love to help you reflect your vision, and your signature result, with ease.