What is Anodizing?

It is an electrochemical oxidation of the aluminum surface to produce a stable film of aluminum oxide ($\text{Al}_2\text{O}_3$).

- Aluminum is “rusted”
  - artificially and uniformly
- Electricity and Chemicals required
  - electrical current passes through aluminum immersed in an acid solution
Anodic Coating Properties

- **Abrasion Resistance**
  - only diamond is harder

- **Corrosion Resistance**
  - withstands salt spray and CASS testing

- **Thermal Resistance**
  - aluminum substrate will melt before the coating

- **Electrical Resistance**
  - 800 V required to pass a current through 1 mil of coating

- **Porous**
  - allows for the coloring and sealing of the coating
# Common Process Steps

1. Racking  
2. Cleaning  
3. Etching  
4. Desmutting  
5. Anodizing  
6. Coloring  
7. Sealing  
8. Unracking  
9. Packing  
10. Lab Testing

Aluminum Anodizing
Racking

- Provides a secure connection for transportation of the parts through the various chemical solutions.

- Provides a secure connection for the flow of electricity through each individual part.

- Allows for uniformity and consistency of current flow from part to part.
Clean, Etch, and Desmut

Cleaning - heated, nonetching alkaline cleaner (10 min)
- removal of most shop residues and fabrication oils
- no removal of adhesives, greases, or buffing compounds

Etching - heated sodium hydroxide (0-20 min)
- roughens the surface to provide a matte finish
- limited success at obscuring scratches, die lines, and bearing marks
- removal of aluminum 0-2.5 mil (0-65 microns) per side

Desmutting - ambient acid bath (1-5 min)
- removes etch smut resulting from alloying constituents
Anodizing

- Immersion in chilled 10% (v/v) sulfuric acid bath
- DC current applied at densities of 8-20 amps/ft²
  - Time varies based on coating thickness (10-60 minutes)
- Barrier layer formed first to a 0.0005 mil thickness
- Coating builds to a 1.0 mil (25.4 μm) max. thickness
- Pores develop as the acid solution dissolves the coating
  - 250 - 500 billion pores per square inch
- Part dimensions increase as the coating is 40% penetration and 60% build-up from the pre-anodized surface
Cross Sectional View of a Dyed and Sealed Anodic Film

Ni(OH)$_2$ precipitate, absorbed dye, & hydrated coating

Hydrated anodic coating

Non-hydrated anodic coating

Aluminum substrate
Types of Anodic Finish

- Clear
- Hardcoat
- Absorptive dye
  - Uptake of organic or inorganic molecules
- Electrolytic Two-step
  - Tin Deposition
  - Cobalt Deposition
- Other
  - Integral Color
  - Overdye
## Clear Anodic Finish

- Translucent film allows the aluminum substrate surface to be visible
- Coating thickness varies based upon specification

<table>
<thead>
<tr>
<th>Alum. Assoc. Specification</th>
<th>Coating Thickness</th>
<th>ALCOA Specification</th>
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<tbody>
<tr>
<td>A21</td>
<td>&lt;0.1 mil or &lt;3 microns</td>
<td>Flash</td>
</tr>
<tr>
<td>A211</td>
<td>0.1 mil or 3 microns</td>
<td>201</td>
</tr>
<tr>
<td>A212</td>
<td>0.2 mil or 5 microns</td>
<td>202</td>
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<td>A31</td>
<td>0.4 mil or 10 microns</td>
<td>204</td>
</tr>
<tr>
<td>A41</td>
<td>0.7 mil or 18 microns</td>
<td>215</td>
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</tbody>
</table>
Hardcoat Anodic Finish

- Low temperature anodizing
- Coating (aluminum oxide) density greatly increased over standard anodizing
- High wear or abrasive applications

1) Aluminum substrate
2) Anodic Coating
Dyed Anodic Finish

- Absorption of either organic or inorganic molecules into the pores of the coating (2-30 min)
- Limitless range of colors
- Typically less fade resistance than other colored anodic finishes

1) Aluminum substrate
2) Anodic Coating
3) Organic/Inorganic Dyestuffs
Electrolytic (2-Step) Color

- Step 1: Clear Anodize
- Step 2: Electrolytic Color
  - AC plating of metal in the base of the coating pores
  - Bronze colors ranging from Champagne to Black (2-25 min)

1) Aluminum substrate
2) Anodic Coating
3) Metal Deposit - either Tin or Cobalt
Sealing

- **Unsealed** - Excellent base for paint and adhesives
- **Hydrothermal Seal** - 200-205 F (15-60 min)
  - Temperature drives coating hydration causing coating expansion to squeeze shut the pores at the surface
- **Mid-Temperature Seal with Metal Salts** - 180 F (15 min)
  - Deposition of metal salts in pores and some sealing by hydration
- **Room Temperature Seal** - 90 F (15 min)
  - Creation of a “super molecule” at the surface consisting of coating, metal salts, and fluoride
  - Prone to causing green tints or a fuzzy surface
Unracking and Packing

- **Unracking - First Inspection Point**
  - Appearance
  - Coating Thickness
  - Seal Quality

- **Packing - Second Inspection Point and Packaging**
  - Type
  - Size
  - Materials
Laboratory Testing

- Coating Thickness - ASTM B244 - Eddy Current
- Coating Weight - ASTM B137 - Acid Dissolution
- Seal Quality
  - ASTM B136 - Modified Dye Stain
  - ASTM B680 - Acid Dissolution
- Abrasion Resistance - FED-STD-141 Method 6192.1
- Gloss - ASTM D523
- Corrosion Resistance
  - ASTM B117 - Salt Spray
  - ASTM B368 - CASS
Advantages of Anodizing

- Highly durable
- Inexpensive to produce and maintain
- Won’t chip, flake, peel or chalk
- Maintains metallic appearance of aluminum
- Environmentally friendly
  - No VOC’s
  - No heavy metals
  - Byproducts aid municipal wastewater treatment facilities to separate solids and neutralize pH
Maintenance

Anodizing: The Renewable Finish

- Accumulated dirt and stains can be removed with a mild detergent applied with an abrasive cleaning technique
- AAMA 609.1 Voluntary Guide for Cleaning and Maintenance of Architectural Anodized Aluminum
Metallurgical Factors

- Alloy and temper selections
- Mixed alloys - various products
  - Extrusion, sheet, forming, casting
- Extrusion defects
  - Hot spots, corrosion, die lines, bearing marks
Specifying Anodizing

- Aluminum Association Designation
  System for Aluminum Finishes
  - Example: AAM12C22A31
  where AA = Aluminum Association
  where M = Mechanical finish
  where C = Chemical pretreatment
  where A = Anodic coating process