TECHEVON LLC
METAL FINISHING SOLUTIONS

Effect of Pretreatment on Appearance of Anodic Coating

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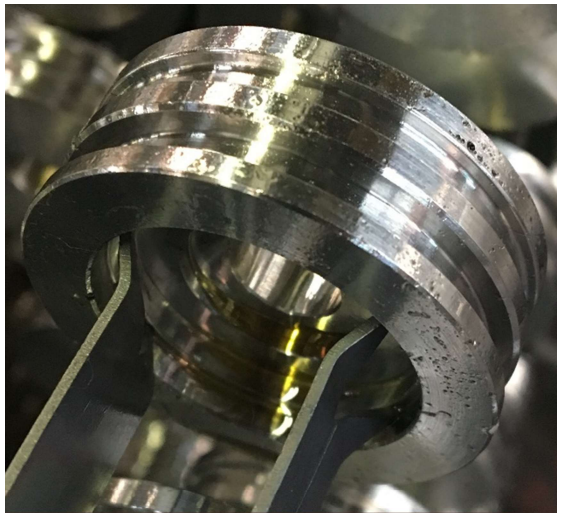
Objective

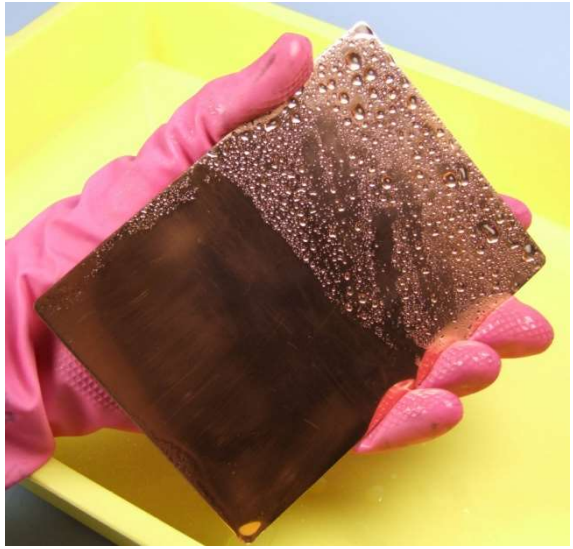
- This paper will discuss the pretreatment possibilities for aluminum prior to anodizing and the effect on color.
- We will discuss different methods of mechanical as well as chemical pretreatments that are considered and their effect on color
- We will review the effect on color using visual observations as well as spectral analysis using a Spectrophotometer.

Agenda

- Purpose of Pre Treatment
- Types of Pre Treatment
  - Mechanical
  - Chemical
- Chemical Pre Treatment for Anodizing
- Pre Treatment Examples
- Common Issues/Challenges
- Final Thoughts/Considerations

Purpose of Pretreatment





- The pretreatment process serves both functional and cosmetic use.
- Functionally the pretreatment process is required to do the following
  - Remove machining oils
  - Remove shop handling stains
  - Remove extrusion die lines
  - Remove natural oxides
  - Clean surface for consistent anodizing
- Cosmetically the pretreatment process is used to achieve the following
  - satin matte finish
  - bright finish
  - mechanical blasting finish

Types of Pretreatment: Mechanical

Process	Description	Advantages	Disadvantages
Abrasive Blasting	• High pressure fluid is used to propel media (i.e. sand, metal shot, glass bead) onto aluminum surface • Used to smoothen rough surfaces, roughen a smooth surfaces and remove surface contaminants.	• Provides matte finish that is appealing for components particularly armament industry components	• If media is not managed or consistent then significant variations in finish can occur
Grinding	• Creates a flat surface aluminum while a rotating abrasive wheel removes surface contaminants	• Provides cosmetic granular look that is popular for certain personal electronic components	• Grinding aluminum can cause pieces to clog the cutting wheel and damage the surface
Polishing	• A cloth with abrasive grains is run over the aluminum to create a reflective finish	• Creates a bright reflective finish that is very appealing for cosmetic parts	• Polishing pressure and abrasive grains must be consistent otherwise this can cause bending of aluminum or variation in finish
Buffing	• Similar to the polishing process however uses less abrasive grains to smoothen the surface of the aluminum.	• Creates a bright reflective finish that is very appealing for cosmetic parts	• Buffing pressure and abrasive grains must be consistent otherwise this can cause bending of aluminum or variation in finish
Tumbling (Mass Finishing)	• Tumbling/ Mass is a process where parts are placed into a rotating barrel with media inside in order to smoothen a rough aluminum surface.	• Removes sharp/rough edges on aluminum parts for easier handling and uniform look	• Media and barrel speed must be consistent to avoid variation in finish or damaged parts

Types of Pretreatment: Chemical

Process	Description	Advantages	Disadvantages
Alkaline Cleaners	• Cleaners that use alkalinity to neutralize acids in lubricants/oils to create a clean surface for etching	• Powdered cleaners are particularly effective for aluminum in neutralizing acid oils creating an oil free surface that is clean for processing	• In some cases can etch aluminum parts resulting in appearance issues
Acid Cleaners	• Designed of parts that have been degreased or have very little oil which require a very mild clean with little to no caustic etching	• Mild cleaning • Limited to no etching of parts	• Not as effective in removing oils from machining
Caustic Etch	• Alkaline based etch which dissolves the top layer of natural oxide and aluminum in order to expose a virgin metal for anodizing	• Economical chemistry used to remove top surface of aluminum only • Helpful to achieve duller appearance on parts • Compatible to Titanium racking	• Can affect machining tolerances if etched too long • Reduce brightness of parts • May cause staining if not rinsed thoroughly
Acid Etch (Fluoride Based)	• Fluoride based Acid which provides a micro etch that is very effective to remove surface defects in extrusions	• Removes extrusion die lines and creates clean surface free of markings	• Requires extensive sludge management equipment and high investment including Ammonia tower • Can attack Titanium racking
Acid Etch (Non Fluoride Based)	• Non Fluoride based Acid which can provide both matte and bright finish depending on temperature of tank	• Remove tarnishing on castings to create bright finish • Can be used to get matte and bright finishes depending on temperature	• Cannot remove extrusion die lines on parts
Bright Dip	• Phosphoric Acid based chemistry that is used to brighten parts for cosmetic appeal	• Produces a mirror bright finish on alloys that can be bright dipped.	• Will brighten a broad range of aluminum alloys and is particularly good for bright dip alloys
Electro Polish	• Phosphoric Acid based electrolyte that when current is applied creates a bright finish similar to bright dip	• Can produce a very bright finish on specific alloys and remove fine scratches.	• Requires large power source and line of sight placement to cathode • Alloy specific

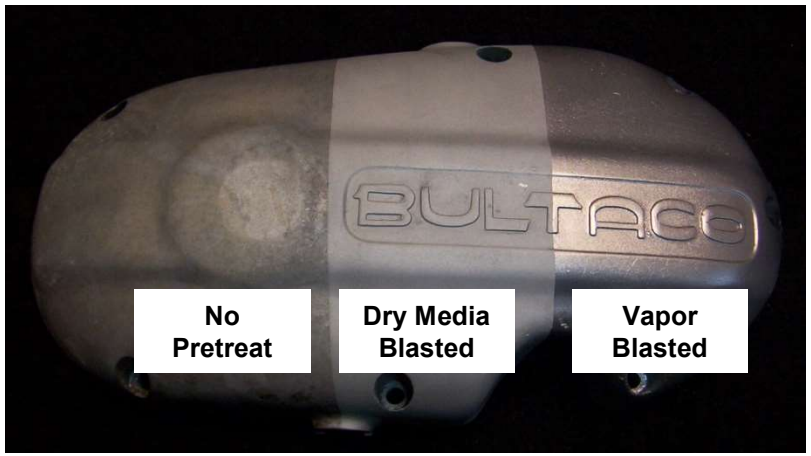
Chemical Pre Treatment for Anodizing

- In typical anodizing operation there are 3 primary pre treatment steps that focus on the following:
  - Removing grease/oils from inbound parts
  - Removing natural oxides and exposing a clean aluminum surface for anodizing
  - Removing oxide scale and residual chemicals associated with caustic etching

Pretreatment Process	Purpose	Factors to Consider
Cleaner	• Remove machining oils • Remove shop handling oils	• Machined components may have buffing compounds which are difficult to remove • Certain cleaners may leave a film on the aluminum which is not desirable for the end customer
Etch	• Remove natural oxides • Provide a satin matte finish • Clean surface for anodizing	• Depending on the type of mechanical pre treatment used a longer etch can make a part less visually appealing • Etch time and concentration is critical to achieving the desired finish
Deox/DeSmut	• Remove oxide scale from surface • Remove any other residual chemicals formed during etching • Clean the surface of aluminum for anodizing	• Based on the aggressiveness of the etch solution used a longer deox/desmut maybe required • Additionally in some cases a Deox with some etching capability may help improve the finish

Pretreatment Type: Mechanical Finishing

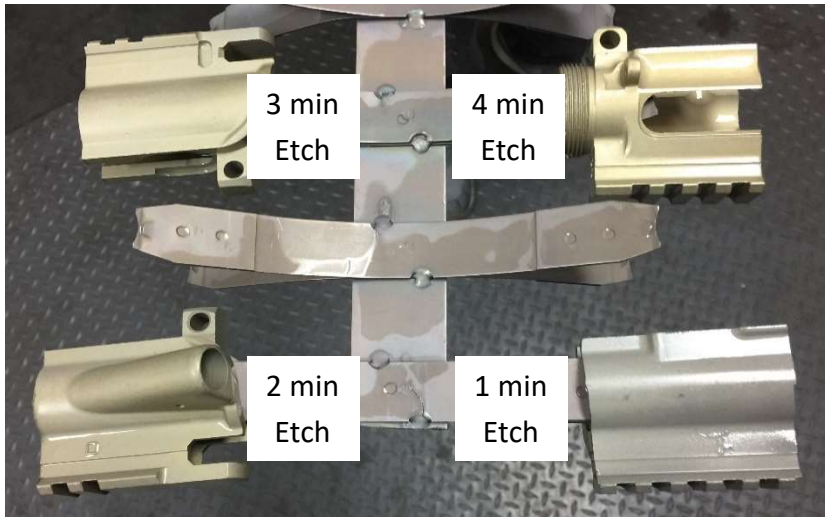
Examples of Mechanical Treatment

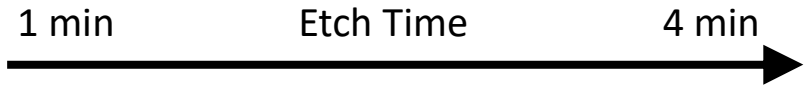


- Difference between an original weathered finish, dry media blasting and a vapor blasted finish.
- Most common examples include
  - Sand blasting
  - Brush / time saver
- Advantages
  - Provides a very appealing matte finish
  - Hides extrusion as well as machining defects
  - Depending on media selected there is flexibility on finish
- Disadvantages
  - If media is not maintained there could be variation in finish
  - Manual vs automated mechanical finishing can also result in variations of finish

Pretreatment Type: Alkaline Etch

Examples of Alkaline Etch





- Alkaline Etching is by far the most common method to pre treat aluminum prior to anodizing
- Advantages
  - Most cost effective method to remove oxides
  - Can create duller finish where desired
  - Less likely to attack non aluminum metals (Cu, Ti, Zn, Mg) than acid etch chemistry thereby limiting pitting
  - Compatible with titanium racking
- Disadvantages
  - Does not hide extrusion defects as well as acid fluoride etches
  - Dull finish requires more metal removal than acid fluoride etches

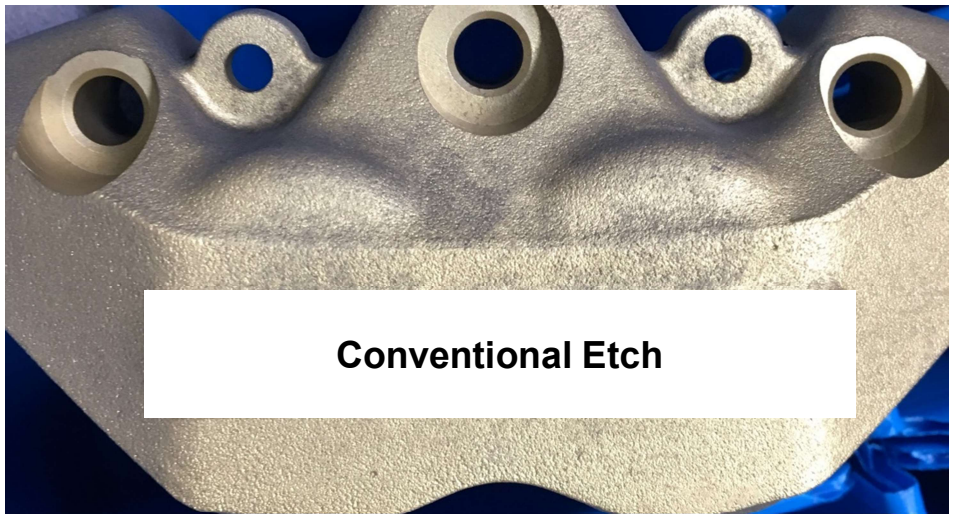
Pretreatment Type: Acid Etch (Fluoride)

Examples of Non Fluoride Acid Etch Parts

- Fluoride based acid etch technology is used for many architectural applications to help mitigate surface defects associated with extruding aluminum
- Advantages
  - Less metal removal for good dull finish
  - Can hide extrusion defects
  - Not compatible with titanium racking
- Disadvantages
  - Increased chemical cost
  - Ammonia odder
  - Filtration Equipment Required
  - Increased waste treatment cost

Pretreatment Type: Acid Etch (Non Fluoride)

Examples of Non Fluoride Acid Etch Parts



- Advantages
  - Brightens some casting compared to duller caustic etch pre treat
  - Does not require extensive investment in waste treatment (i.e. Ammonia tower)
  - Can be adapted for electropolish applications
  - Compatible with titanium racking
  - Operating temperature can be used to manage dullness and/or brightness of part
  - Excellent results when used with mechanical pretreatments such as media blasting and brush finish
- Disadvantages
  - More expensive than caustic etches
  - Needs corrosion resistant equipment
  - Needs elevated temperatures

Pretreatment Type: Bright Dip

Examples of Bright Dipped Parts

- Bright dipping is used to achieve a brighter high gloss finish on aluminum parts.
- These are parts that are typically used for highly cosmetic applications
- There are number of factors to consider when using bright dip chemistry some of which include the following
  - Not all alloys can be bright dipped therefore alloy selection is critical
  - Due to the high phosphate concentration of bright dip solutions waste treatment can be expensive
  - NOX fumes require extensive air purification equipment
  - Titanium tooling can be used
  - Phosphate drag out to subsequent tanks can cause finish and/or seal problems

Pretreatment Type: Electropolish

Examples of Bright Dipped Parts

- Electropolishing is another pretreatment process similar to bright dip that is used to create a gloss finish on aluminum parts.
- There are number of factors to consider when using electropolish chemistry which are following
  - Electropolish is even more dependent on the alloys as compared to chemical brightening and so alloy selectin is even more critical
  - Rectifier is required
  - There is a limited amount of deburring action which can help cover fine handling defects
  - Due to the high phosphate concentration of bright dip solutions waste treatment can be expensive
  - No NOX fumes associated with Electropolish

Pretreatment Effect Study

- The next slides represent a study we performed to analyze the effect of various pre treatments. With that said below are the operating parameters for this study:
  - **Mechanical Pretreatment**: We used media blasting and time saving (brush finish) since they are two of the most common mechanical pretreatments
  - **Chemical Pretreatment**: We used a NOX free acid etch on some alloys to produce a bright finish at higher temperatures and a dull finish at lower temperatures. The other chemical pretreatment was the common alkaline etch used in all anodizing plants.
  - **Colors/Dyes**: We selected dyes that would help us understand the effect of a non-saturated coating (grey dye) and a saturated coating (red dye)
  - **Alloy Type**: We used 3 types of alloys: high purity bright alloy (1052), Stamping alloy (5052) and machined parts alloy (6061)
  - **Sealing**: all panels were sealed in Hot Nickel Acetate seals
- After processing each part we performed color evaluations using a Macbeth 3000 color eye spectrophotometer.

Pretreatment Example: Brush Finish Clear

- Acid Etch Brush Finish

Clear Brush

1000 series dE 1.776

Clear Brush

5052 dE 0.224

Clear Brush

6061 dE 0.852

Pretreatment Example: Sand Blast Finish Clear

- Acid Etch Sand Blasted Finish

Clear Blasted

1000 series dE 0.774

Clear Blasted

5052 dE 0.457

Clear Blasted

6061 dE 3.091

Pretreatment Example: Brush Finish Clear

- Caustic Etch Brush Finish

Clear Brush

1000 series dE 2.408

Clear Brush

5052 dE 2.734

Clear Brush

6061 dE 1.578

Pretreatment Example: Sand Blast Finish Clear

- Caustic Etch Sand Blasted Finish

Clear Blasted

1000 series dE 9.157

Clear Blasted

5052 dE 8.413

Clear Blasted

6061 dE 0.453

Pretreatment Example: Brush Finish Grey

- Acid Etch Brush Finish

Grey Brush

1000 series dE 0.637

Grey Brush

5052 dE 0.308

Grey Brush

6061 dE 1.225

Pretreatment Example: Sand Blast Finish Grey

- Acid Etch Sand Blasted Finish

Grey Blasted

1000 series 0.442

Grey Blasted

5052 dE 0.315

Grey Blasted

6061 dE 1.540

Pretreatment Example: Brush Finish Grey

- Caustic Etch Brush Finish

Grey Brush

1000 series dE 1.641

Grey Brush

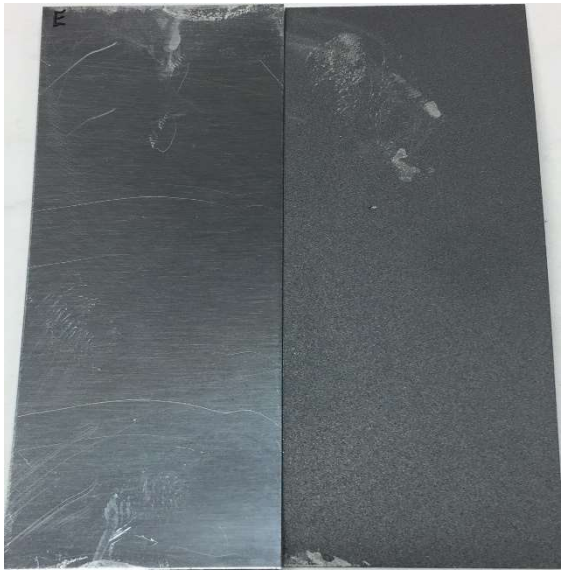
5052 dE 1.088

Grey Brush

6061 dE 2.858

Pretreatment Example: Sand Blast Finish Grey

- Caustic Etch Sand Blasted Finish



Grey Blasted

1000 series dE 11.146

Grey Blasted

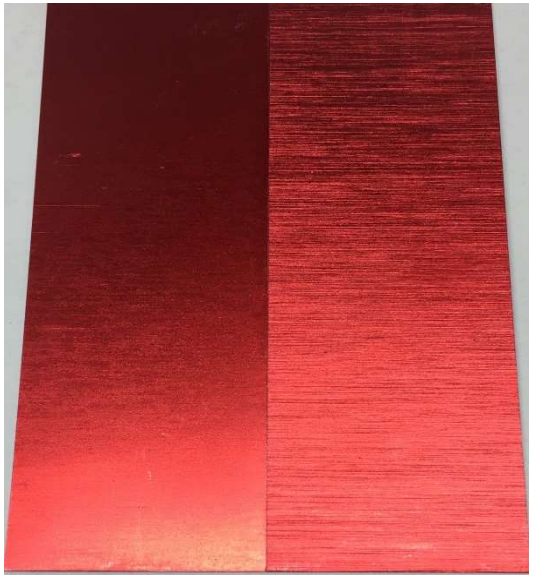
5052 dE 5.647

Grey Blasted

6061 dE 4.859

Pretreatment Example: Brush Finish Red

- Acid Etch Brush Finish



Red Brush

1000 series dE 0.647

Red Brush

5052 dE 3.878

Red Brush

6061 dE 1.323

Pretreatment Example: Sand Blast Finish Red

- Acid Etch Sand Blasted Finish

Red Blasted

1000 series dE 2.009

Red Blasted

5052 dE 3.961

Red Blasted

6061 dE 1.370

Pretreatment Example: Brush Finish Red

- Caustic Etch Brush Finish

Red Brush

1000 series dE 6.075

Red Brush

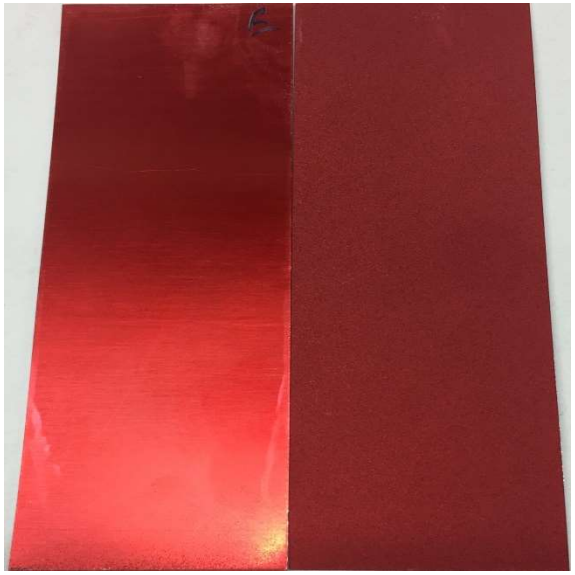
5052 dE 1.467

Red Brush

6061 dE 1.513

Pretreatment Example: Sand Blast Finish Red

- Caustic Etch Sand Blasted Finish



Red Blasted

1000 series dE 15.262

Red Blasted

5052 dE 12.259

Red Blasted

6061 dE 4.483

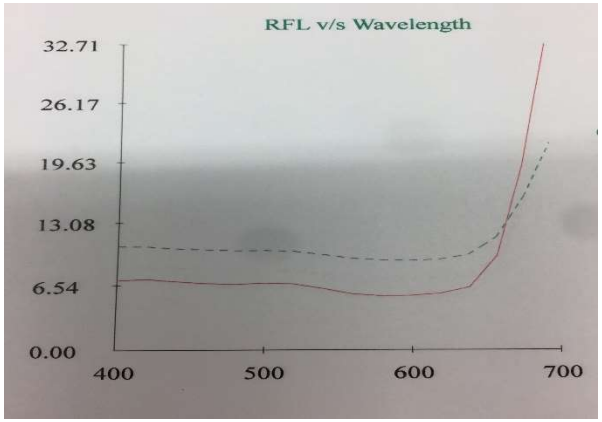
Pretreatment Effect Observations

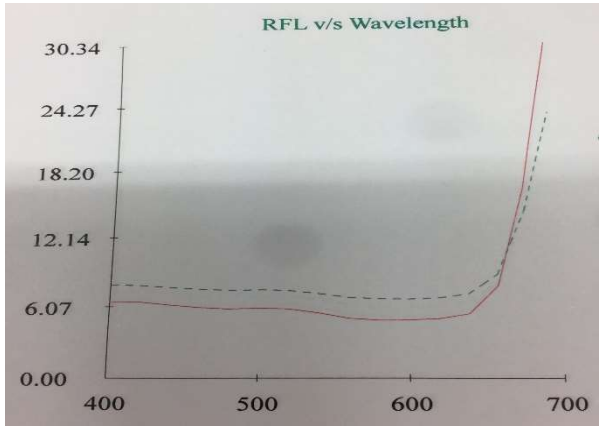
Panel Type	Acid Etch Treatment	Caustic Treatment
Clear Anodized	• Less color difference on brush finish as compared to blasted finish • 6061 alloy type shows the most difference	• Compared to the acid etch the caustic etch parts show more variation in color
Grey Dye (Non Saturated Coating)	• Less color difference on brush finish as compared to blasted finish	• Compared to the acid etch the caustic etch shows significantly more color variation
Red Dye (Saturated Coating)	• Less color difference on brush finish as compared to blasted finish	• Compared to the acid etch the caustic etch shows significantly more color variation

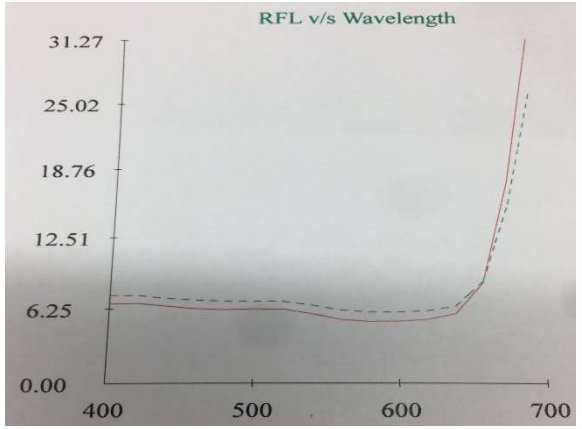
If a caustic etch is selected as a chemical treatment, care must be taken to establish the amount of caustic etching that must be done and the etch rate must be consistent in order to avoid variations in brightness of the finish.

Pretreatment Example: Sand Blast & Caustic Etch

- This slide shows the appearance difference as a result of different etch times





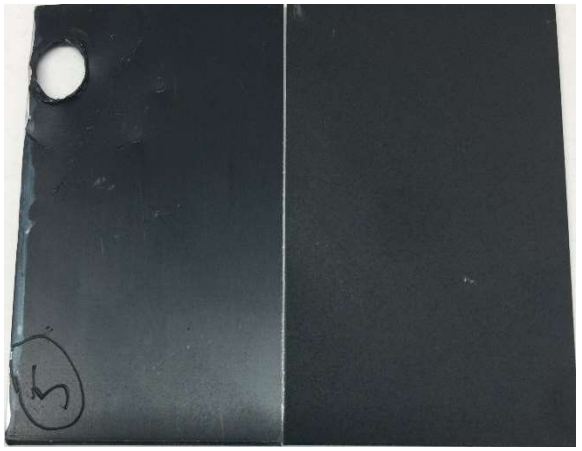


No Blast Blasted

1 min Etch dE 7.491

No Blast Blasted

2 min Etch dE 4.205



No Blast Blasted

5 min Etch dE 1.789

Pretreatment Example: Sand Blast & Caustic Etch

- The images below show the effect of etch time/rate on a sand blasted part that was dyed black
- Based on this information marring is more likely on parts that are etched for a shorter period of time as you can see on the image on the left.

1 min Etch	**3 min Etch**	**5 min Etch**
Significant Marring	Moderate Marring	Little to No Marring

Pretreatment Effect on Appearance

- To further understand the reason for the appearance difference of the blasted finish and the non-blasted finish coating weights were done on the panels to understand if the coating characteristics were different and the results reported below:

Etch Duration	Media Blasting	Coating Weight (mg/in^2)
1 Min	Sand Blasted	14.141
3 Min	Sand Blasted	15.516
5 Min	Sand Blasted	15.741
5 Min	No Blasting	28.801

- Based on this data we can conclude that the media blasting increases the surface area of the part and so the coating weight drops.
- The process of etching reduces the roughness (thus reducing the surface area) and the coating weights get better, but in no case is the coating weight close to that of not media blasted panels.
- Increasing the current density might be a good option to improve coating weights of media blasted parts.

Common Issues/Challenges: Inconsistent Finish

- An inconsistent finish can result from any of the following:
  - Pretreatment variations (mechanical and/or chemical)
  - Alloy type
  - Dye type
  - Anodizing parameters
- The most common reasons for an inconsistent finish are primarily found in the pretreatment. Specifically in the following areas:
  1. Mechanical Pretreatment
     - If the media blasting is not uniform the part can show a wavy pattern
     - If the media has broken down and not replenished at the appropriate time the finish will have a different appearance.
  2. Chemical Pretreatment
     - Too short of an etch will leave the end product less deep in color and will mar very easily.
     - Too long of an etch will make the part more reflective (for media blasted parts) and might bring out the grain in the material.
     - Inconsistent etch rate (aggressive vs moderate)

Final Thoughts/Considerations

- As a whole the **pretreatment selection is a critical process step** before anodizing and must be fully understood to avoid inconsistent finishes. There are number of factors to consider when assessing pretreatment options
  - Is there a desired cosmetic requirement (i.e. matte vs bright, clear vs dyed)?
  - What is the condition of inbound parts (i.e. oily, extrusions defects, varied mechanical treatment,)?
- Certain **techniques can be used to mitigate issues with pre treatment**.
  - **Increasing etch time** on blasted parts reduces the likelihood of marring thereby making a more aesthetically pleasing part
  - **Dyeing to saturation** can reduce variability in pretreatment finish whereas lighter colors that are not dyed to saturation are more susceptible to appearance variation
  - Since media blasted parts have more surface are than non blasted parts one can **increase current density** to achieve coating weights comparable to non blasted parts
  - Increasing the etch time can reduce the roughness of blasted parts resulting in improvements to coating weight.
- If the pretreatment process is well established and repeatable and components become inconsistent, then factors such as the choice of dye, effect of contaminants, apparent and effective dye concentration and sealing method must be considered.

Questions

References

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