TECHEVON LLC
METAL FINISHING SOLUTIONS

Cosmetic & Functional Hardcoat

Presented By:

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Executive Summary & Overview

- For the purposes of this presentation Type II will be referred to as **Conventional Anodizing** and Type III will be referred to as **Hard Anodizing (Conventional and Modified Hard Anodizing)**
- Hard Anodizing is largely a functional coating and for most applications' durability is the driving force as it relates to quality and cosmetic appearance is less critical.
- Certain industries such as the Medical Sector and Armament Industry value the durability associated with hard anodizing.
  - The **medical industry** feels that conventionally anodized components do not perform as well as hard anodized components particularly when subjected to harsh sterilization and autoclave treatments. However, the appearance of hard anodizing limits the ability to broaden the use of anodizing in a wide variety of components because of their need to color code different components.
  - The **armament industry** is considering using hard anodizing more extensively if lighter colors such as tan could be developed using hard anodizing. However, achieving these type of lighter colors can be limited because of the natural color developed by hard anodizing.
- If hard anodizing could be offered with a range of consistent colors, it could open up new markets for the industry. Therefore this paper will discuss some of the possibilities of **offering colored hard anodizing and discuss the performance differences as compared to conventional anodizing**.

Agenda

- Hard Anodizing Overview
- Conventional vs Modified Hard Anodizing
- Coating Hardness & Performance
- Methods to Manage Appearance
- Sealing of Hard Coat
- Cosmetic Hard Anodizing Applications
- Final Thoughts/Considerations

Hard Anodizing Overview

- Hard Coat differs from conventional anodizing in the following ways:
  - Coating is created at higher current density (18 to 24 ASF)
  - Hard coat color can vary significantly by coating thickness and temperature
- Since hard anodizing is done above **18 ASF the heat generated is very high and so to manage heat build up and to promote coating build up the temperature of the electrolyte is reduced.**
- **This reduced temperature lowers conductivity resulting in an increase in voltage.**
- The amount of current density varies based on the alloy
  - Heavily alloyed aluminum uses lower current density
  - Purer alloyed aluminum uses higher current density
- General rules to follow:
  - The thicker the coating and lower the temperature of the electrolyte the darker the color
  - The purer the alloy the lighter the color.
  - 2000 series alloys produce a grayish shades
  - 7000 series alloys produce yellowish shades.
- Hard Anodizing Conditions are below:

	Conventional Hard Coat	**Modified Hard Coat**
Sulfuric Acid	160 – 250 g/L	160 – 250 g/L
Temperature	30 – 34 ºF	45 – 68 ºF
Current Density	18 to 24 ASF	18 to 24 ASF
Voltage	25 – 100	25 – 50
Time	Depends on thickness	Depends on thickness

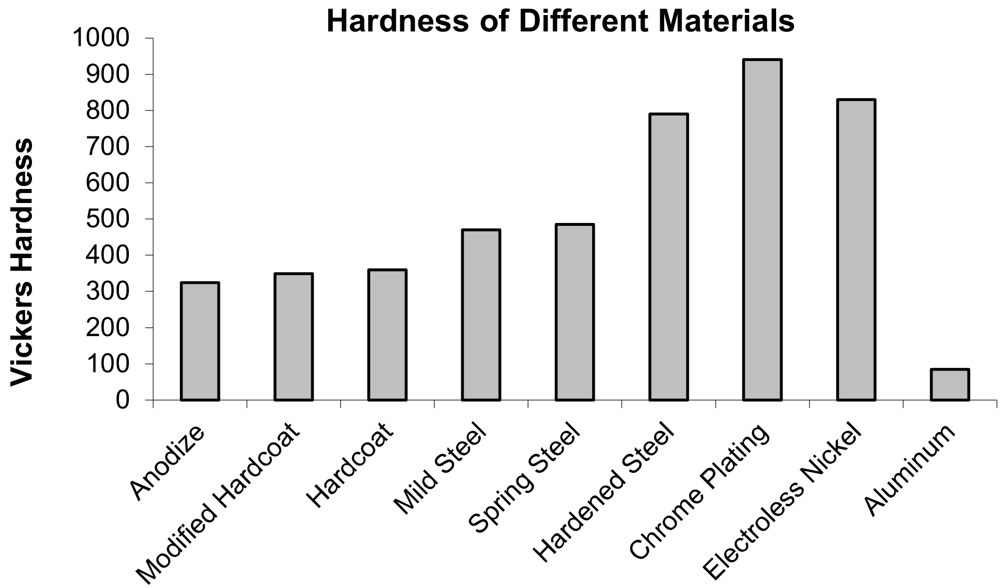
Hard Anodizing Overview: Process Challenges

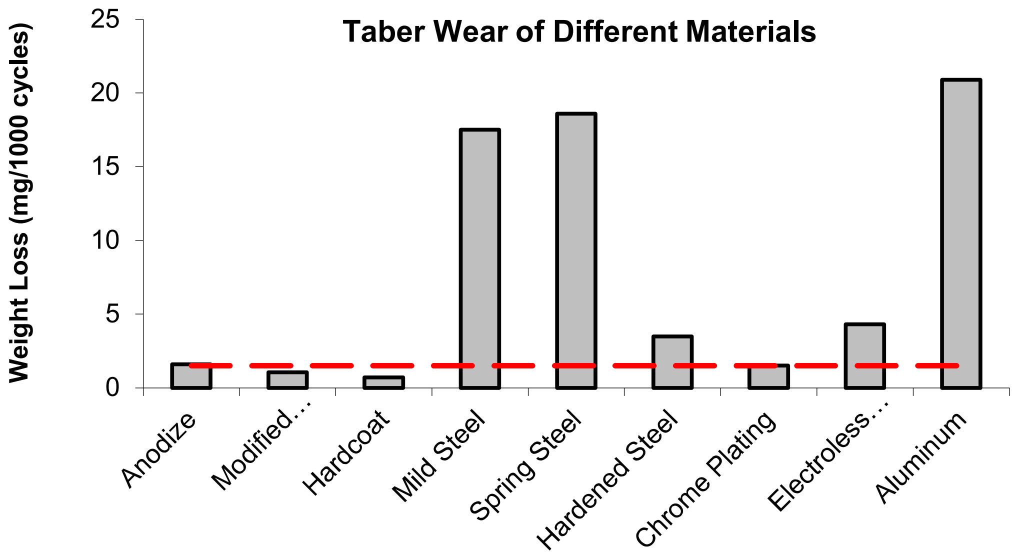
- Hard coating requires higher current densities, so more heat is generated from process which raises the issues below:
  - Refrigeration, pumps & heat exchanges
  - Optimal tooling design
  - Increased voltages and rectification
  - Low coating porosity makes coloring difficult
  - Alloy color variation
- If these issues are not addressed there are several problems that can arise
  - Burning of parts (as seen in the images to the left)
  - Reduced coating density if temperature is not maintained
  - Incorrect color

Coating Hardness: Measurement Methods

- The most widely accepted micro hardness method used to for Hard Anodizing is the Taber Abrasion Test.
- The Taber Abrasion is done using
  - CS17 Wheels
  - Load of 1,000 grams
  - Revolutions of 10,000 revolution
- Another type of micro hardness testing is the Vickers Process
  - Vickers hardness is done by mounting the samples on epoxy mounting material and a minimum thickness of 15 microns is required to get good Vicker's indents
  - The load size for the Vickers Hardness was set at 10 grams
  - Results were averages of multiple readings

Coating Hardness: Measurement Methods

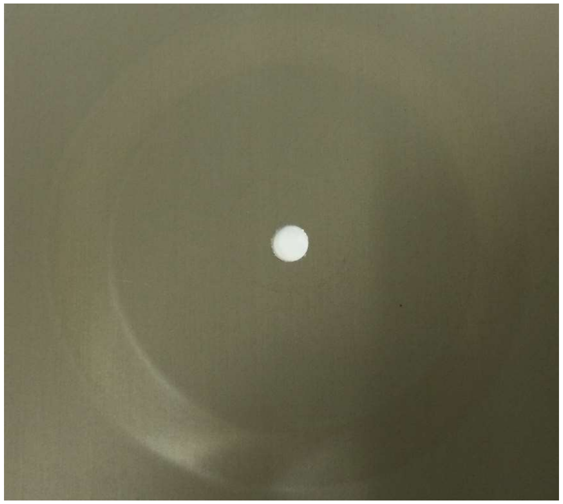




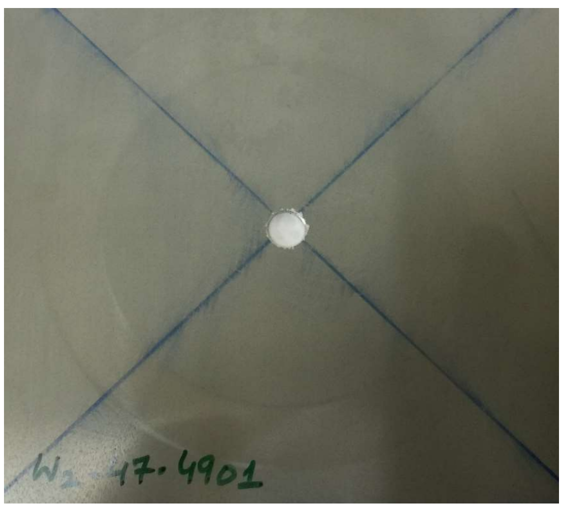
- The graphs to the left show the varying hardness and Taber wear properties of numerous materials used for manufacturing purposes
- The Vickers hardness data indicates that anodized aluminum whether it is hard or conventional does not perform as well as Hardened Steel or Chrome plated surfaces
- However when assessing anodizing under Taber abrasion testing there is a significant improvement.
- Therefore the typical industry metric on determining the quality of hard anodizing is based on Taber abrasion or wear resistance NOT Vickers hardness

Coating Hardness: Modified Hard Anodizing

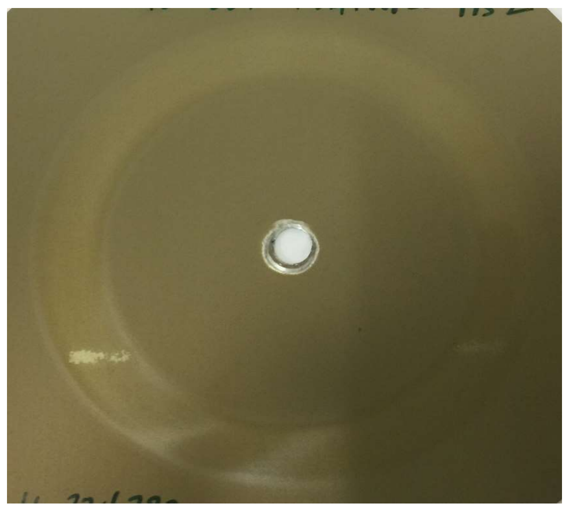
6061 – Wear/1000 cycles: 0.5



2024 – Wear/1000 cycles: 1.38



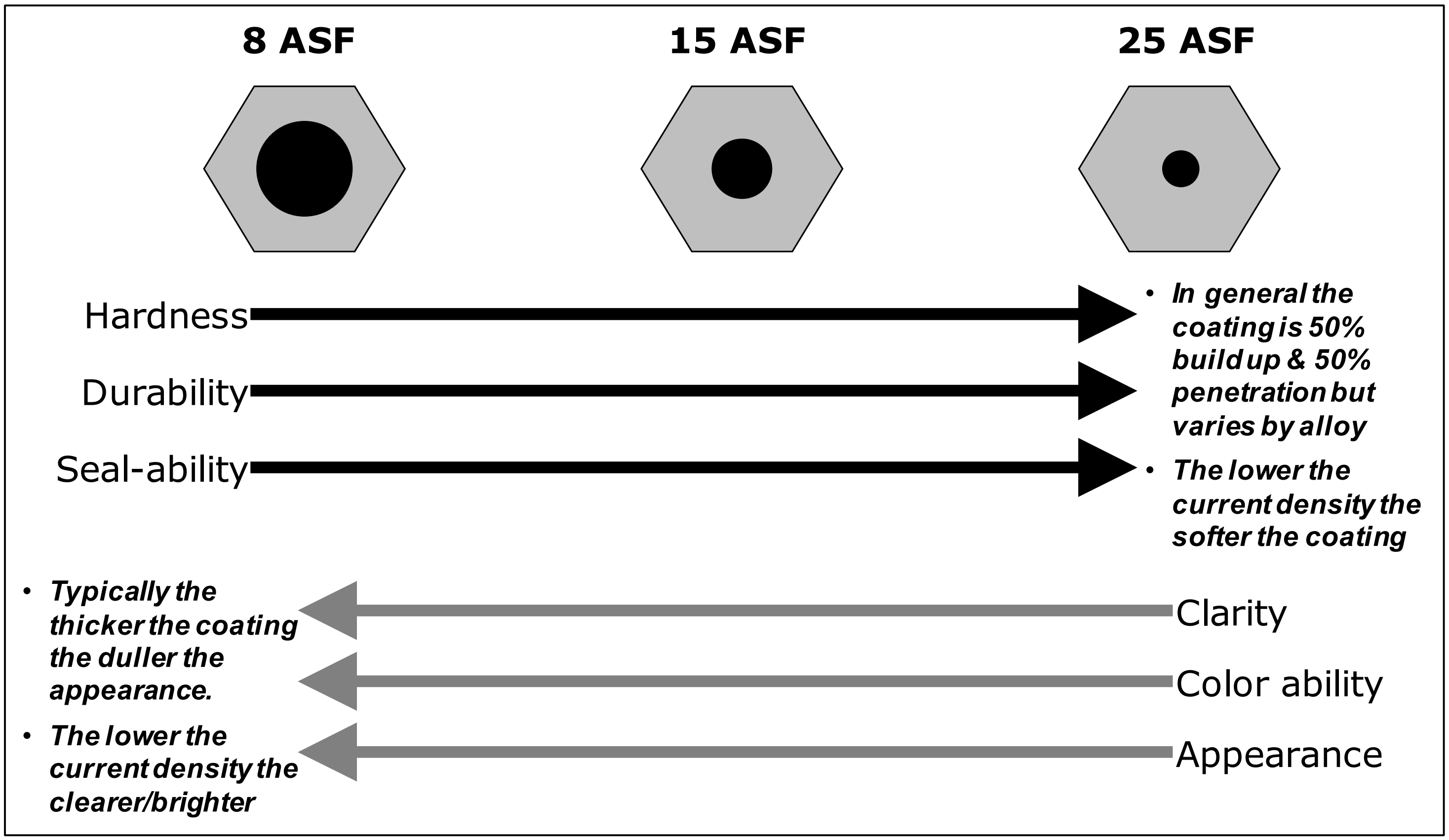
7075 – Wear/1000 cycles: 1.72



- Taber Abrasion Testing was performed on 6061, 2024 & 7075 alloys to evaluate coating hardness.
- Hardness testing was done to in accordance to the Mil-Spec 8625F
- Taber Abrasion is done using the following process:
  - CS17 Wheels
  - Load of 1,000 grams
  - Revolutions of 10,000 revolution

Methods to Manage Appearance

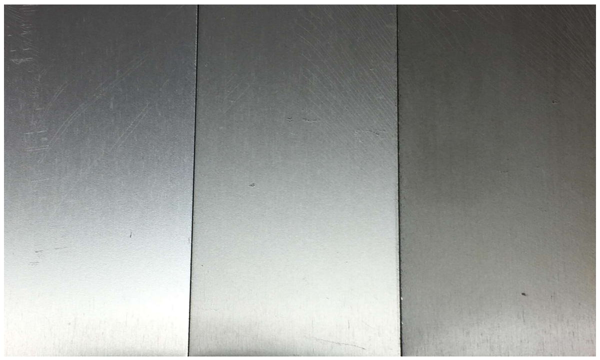
- There are 4 primary factors that contribute to the cosmetic appearance of a hard-anodized part
  - Alloy Type
  - Coating Density
  - Coating Thickness
  - Type of Hard Anodizing Process (Modified vs Conventional)



Methods to Manage Appearance: Alloy

- The pictures below show the variation in natural color for conventional and modified hard anodizing based on thickness and alloy

Conventional Hard Anodizing

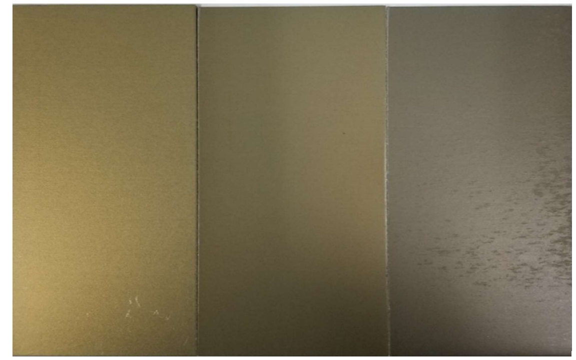


1.0 Mils	1.5 Mils	2.0 Mils
	dE 8.17	**dE 20.08**

2024

1.0 Mils	1.5 Mils	2.0 Mils
	dE 16.81	**dE 21.962**

6061



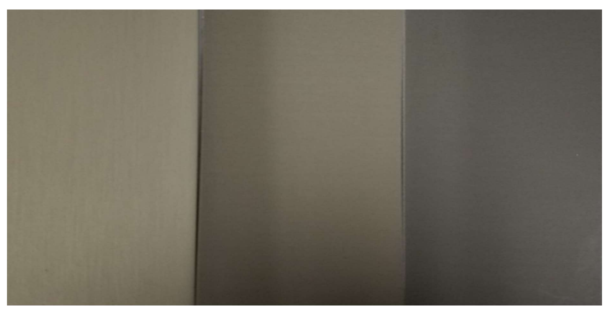
1.0 Mils	1.5 Mils	2.0 Mils
	dE 9.42	**dE 17.51**

7075

Modified Hard Anodizing

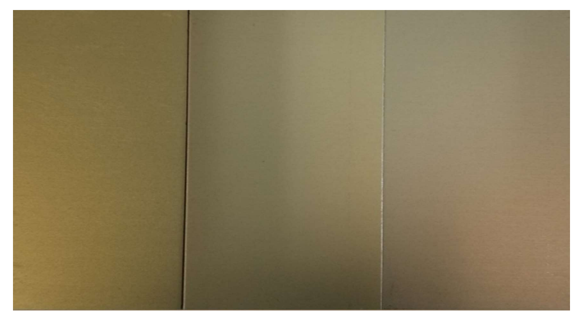
1.0 Mils	1.5 Mils	2.0 Mils
	dE 8.52	**dE 9.38**

2024



1.0 Mils	1.5 Mils	2.0 Mils
	dE 17.47	**dE 23.40**

6061



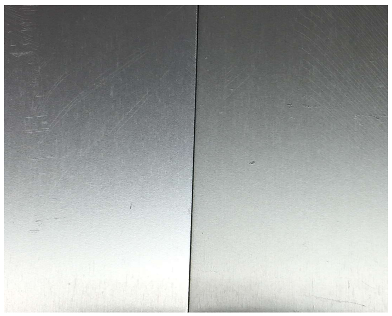
1.0 Mils	1.5 Mils	2.0 Mils
	dE 7.60	**dE 12.66**

7075

Methods to Manage Appearance: Density

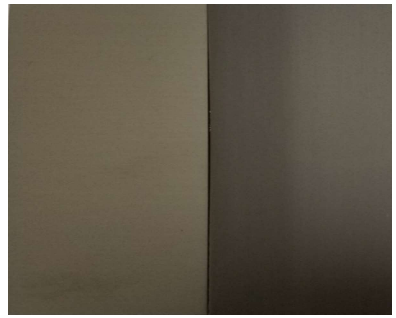
- The pictures below show the variation in natural color for conventional and modified hard anodizing based on thickness and alloy

Conventional Hard Anodizing: 18 ASF or Higher



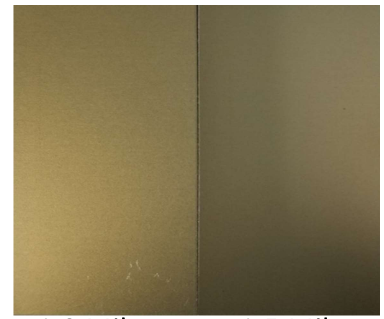
1.0 Mils 1.5 Mils
dE 8.17

2024



1.0 Mils 1.5 Mils
dE 16.81

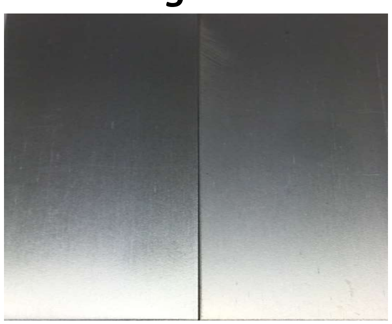
6061



1.0 Mils 1.5 Mils
dE 9.42

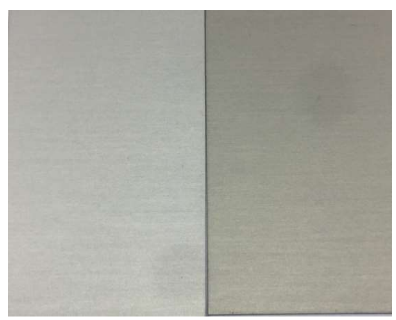
7075

TYPE II Anodizing: 12 ASF or Lower



1.0 Mils 1.5 Mils
dE 6.36

2024



1.0 Mils 1.5 Mils
dE 8.56

6061

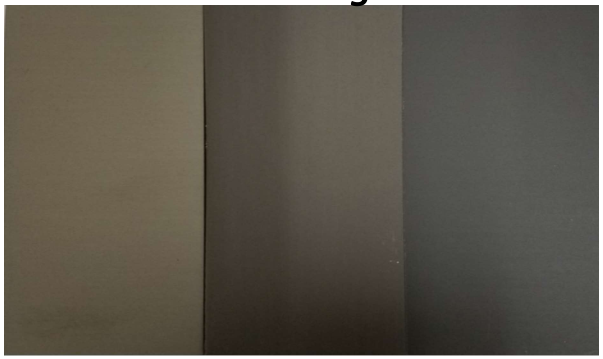
1.0 Mils 1.5 Mils
dE 7.8

7075

Methods to Manage Appearance: Coating Thickness

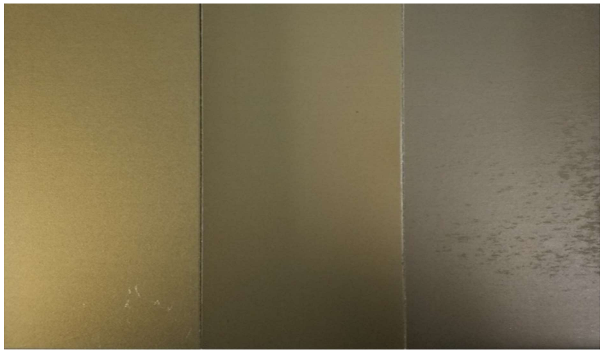
- The pictures below show the variation in color based on thickness for both natural hard coat and dyed hard coat

Natural Hard Anodizing



1.0 Mils | 1.5 Mils **dE 16.81** | 2.0 Mils **dE 21.962**

6061



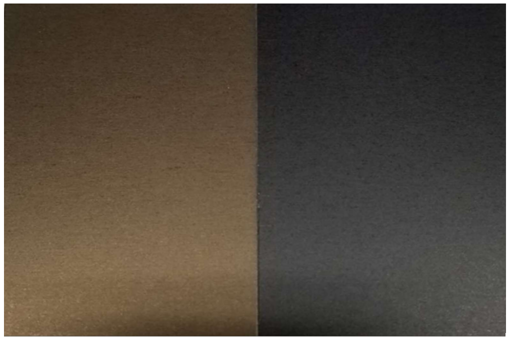
1.0 Mils | 1.5 Mils **dE 9.42** | 2.0 Mils **dE 17.51**

7075

Brown Dyed Hard Anodizing

1.0 Mils | 1.5 Mils **dE 10.79**

6061



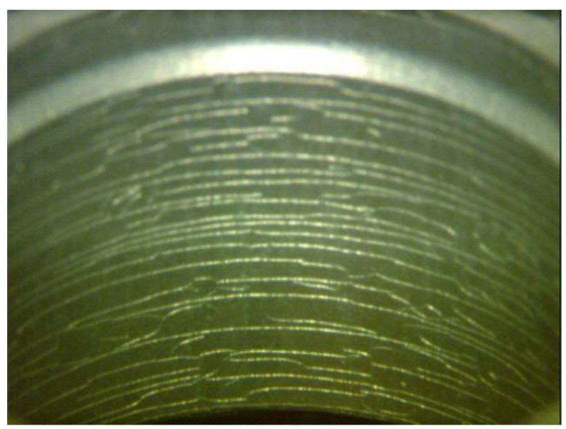
1.0 Mils | 1.5 Mils **dE 13.72**

7075

Sealing of Hard Anodizing

Sealing Method	Temperature Range	Crazing
Hot Nickel	175 to 185 F	Yes
Hot DI Water	>200 F	Yes
Sodium Dichromate	>195 F	Yes
PTFE	Ambient	Minimal
Chromate Conversion	Ambient	Minimal
Cold Nickel	85 to 95F	Minimal

Crazing



- The sealing of Hard Anodizing is different than conventional anodize because in many cases the abrasion resistance must be preserved.
- Therefore it is believed that using a hot seals with DI water reduce the abrasion resistance for hard anodizing so in many cases hard coat parts are left unsealed
- Crazing is another cosmetic factor to consider when hard anodizing. It is caused when the base layer of the anodic coating cracks due to heat expansion associated with hot seals
- Therefore when sealing is required for hard anodizing a cold seal is most often used

Sealing of Hard Anodizing: High Alkaline Resistance

- Today's automotive industry has some of the most difficult seal quality requirements of any application particularly for external components. This is a result of the popularity of touchless car washes which use very alkaline solutions to clean cars.
- Therefore in the next slides we utilized a high alkaline testing procedure to evaluate hard anodizing with both conventional nickel sealing and High Alkaline Resistance (HAR) sealing in order to see how different sealing systems perform.
- The solution used will be the following:
  - 12.7 g/l of Sodium Hydroxide
  - 4.64 g/l of Sodium Phosphate Dodecahydrate
  - 0.33 g/l Sodium Chloride

Sealing of Hard Anodizing: High Alkaline Resistance

Hot Nickel Seal

1.0 Mils 1.5 Mils

6061 Conventional Hard Anodizing

0.4 Mils 0.7 Mils

6061 Type II

High Alkaline Resistance Seal (HAR)

1.0 Mils 1.5 Mils

6061 Conventional Hard Anodizing

0.4 Mils 0.7 Mils

6061 Type II

- Conventional Nickel sealing does not perform well when subjected to Highly Alkaline Solutions
- All panels sealed in with conventional Nickel failed, the order of performance is as follows:
  - Conventional Hard Anodizing (Best)
  - Modified Hard Anodizing
  - Type II Anodizing (Worst)
- The HAR Sealing Method produces a much better response when subjected to Highly Alkaline Solutions.
- The order of performance is as follows:
  - Conventional Hard Anodizing (Best with no attack)
  - Modified Hard Anodizing (Marginal Blemish if any)
  - Type II Anodizing (Low level Blemish)

Cosmetic Hard Anodizing Applications

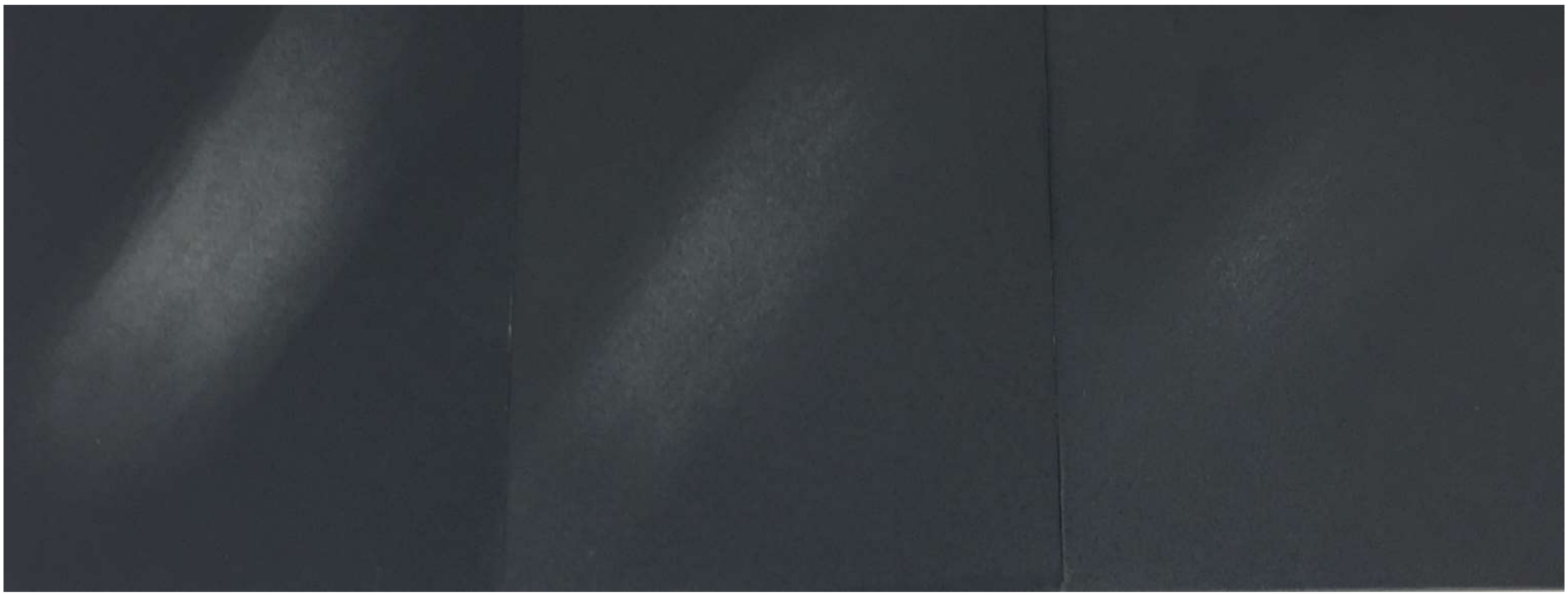
Armaments

Medical Instruments

- There several industry applications that require both the functionality of Hard Anodizing in tandem with Cosmetic appearance
- Most recently the industries below have increased demand in cosmetically appealing hard anodizing
  - Medical Instruments / Components
  - Armament Industry
- These new cosmetic requirements include the following:
  - Minimal surface defects (marring)
  - Brighter/Lighter colors
  - Consistent colors across alloys
  - Increased coating durability as it relates to sterilization processes

Cosmetic Hard Anodizing Applications: Pre-Treatment

- 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

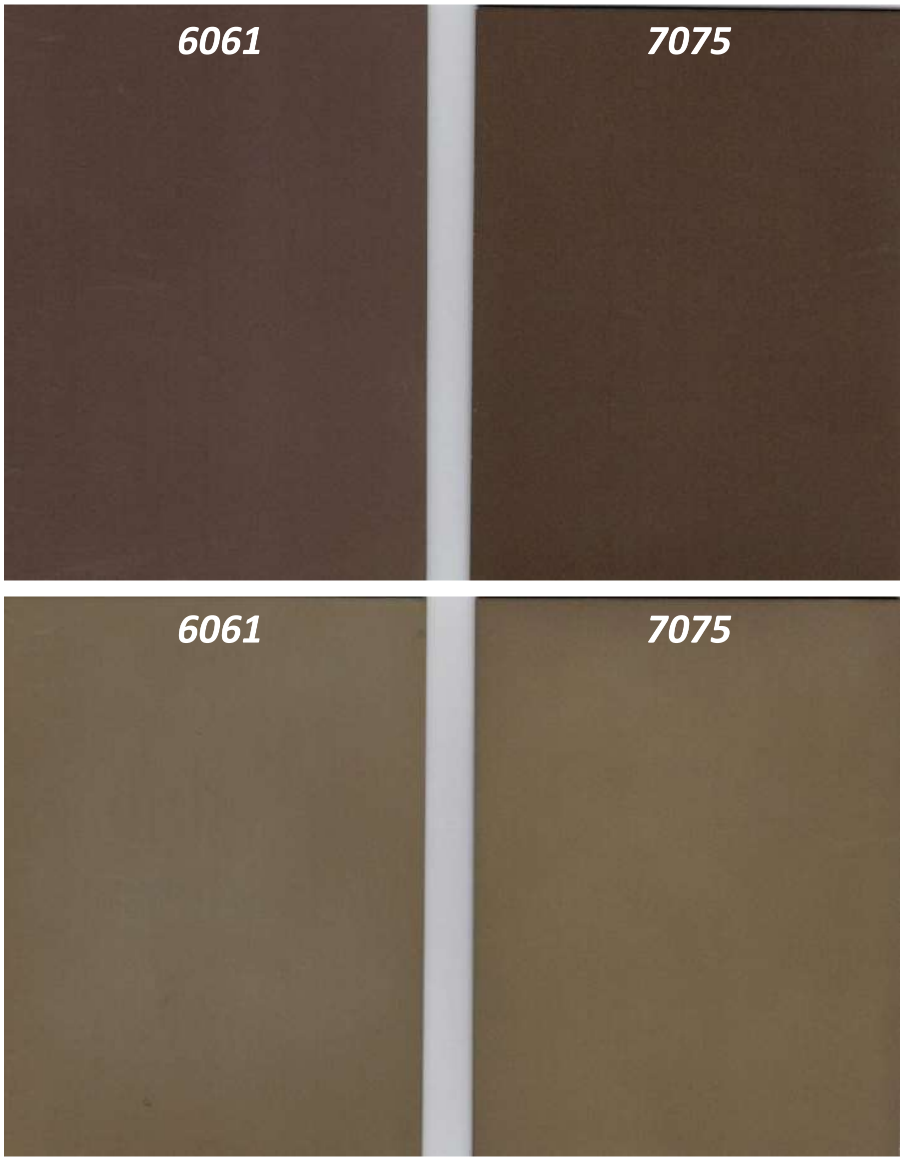
Cosmetic Hard Anodizing Applications: Pre-Treatment

- 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.**

Cosmetic Hard Anodizing Applications: Color



- In the case of armament components it is possible to provide cross alloy finishes that match using hard anodizing
- The most common alloys in the armament industry are 7075 & 6061
- Therefore we processed panels of both alloy types (see left) using modified hard anodizing with different dyes and anodizing conditions
- When the color difference was measured for both the brown and light tan the color difference was below a dE of 3.0 which indicates a colors that have no visible difference to the human eye
- These finishes are achievable in a production environment if process controls are managed correctly along with dye and sealing chemistry

Final Thoughts/Considerations

Coating Appearance

- The appearance of conventional Hard Anodizing limits its suitability for a wide variety of applications particularly when color is a criteria for component selection. Lighter colors are more problematic than darker colors
- Color matching can be difficult for all anodic coatings because of the characteristics hues that coatings develop based on the alloy processed
- These hues become more dominant the harder the coating and the thicker the coating.
- To mitigate the hues developed during hard anodizing components try to get specified with a black color.
- The black dye used is very important particularly when it comes to hard anodizing because not all black dyes will color hard anodizing to a deep uniform black.
- Every black dye has a characteristic hue and, in some industries, a red hue is perceived to be a dye of poor quality. Some industries have developed test methods linked to light sources as a quality control criteria for black coatings.

Final Thoughts/Considerations

Coating Durability

- The durability of Hard Anodizing is significantly better than conventional anodizing as judged by high alkaline resistance & Taber Abrasion
- Conventional Hard Anodizing based on the testing as shown in this presentation is by far the best as it relates to high alkaline resistance
- Modified Hard Anodizing can be a suitable alternative to have durability approaching that of conventional Hard Anodizing with the possibilities of wider applicability particularly when color is desirable. Some lighter colors such as Tan and/or Flat Dark Earth are possible
- Conventional Anodizing offers the best possibilities as it relates to aesthetics but at a significant trade off in durability particularly when compared to Hard Anodizing

Final Thoughts/Considerations

Alloy Variation

- As it relates to the alloys tested in this paper it is safe to say the following for coloring hard anodizing:
  - **2024 produces the best dyeability** since all panels exhibited the best dyeing efficiency/color brightness
  - **7075 produces good dyeability** but the yellow coating hue tends to make a dramatic shift in the color
  - **6061 shows the worst dyeability** because the coating is significantly duller and the grey hue of the undyed coating mutes all of the colors.
- In order to achieve a desert sand, flat dark earth or tan color on 6061 it is difficult to overcome the grey hue which tends to take away the brown that is necessary in those shades. Therefore consider the following:
  - **Evaluate the shade** to determine what color options are viable after hard anodizing.
  - **Manage coating thickness** to avoid excess coating that creates a base metal color which cannot be overcome by dyeing
  - Review the type and amount of components that must be used for the color match to ensure that color ranges are achievable for multi alloy/component assemblies
  - **Assess the type of seal chemistry** used in to mitigate color shift and provide optimal seal quality.

End of Session