Bonding Anodized Aluminum with Adhesives and Tapes

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3-M
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Bonding Anodized Aluminum with Adhesives and Tapes
Presented By:
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Outline
- Bonding Methods – Mechanical and Adhesive
- Introduction to Adhesion
- Test Results – Bonding Anodized Aluminum with adhesives
- Application Examples – Bonding Anodized Aluminum parts with adhesives
**What is Mechanical Bonding?**

Bonding with fasteners (typically metal) that include:
- Bolts
- Clamps
- Rivets
- Screws
- Nuts

**Advantages:**
- Inexpensive
- Immediate strength
- Accepted by industry
- Lower labor rate versus thermal bonding
- Removability
- Little cleaning/ prep needed

**Disadvantages:**
- Substrate distortion
- Appearance/visible bond line
- Substrate fatigue (fastener typically punched through substrate)
- Can harm painted surfaces
- Possible corrosion

**Mechanical Bonding**

**What is Tapes and Adhesive Bonding?**

Creating a permanent or removable bond with:
- Structural Epoxies
- Contact Adhesives
- Cyanoacrylates
- Adhesive Sealants
- Reclosable Fasteners
- Foam Tapes
- Double Coated Tapes
- Transfer Tapes
- Hot Melt
Adhesives and Tapes Value vs. Mechanical Fasteners

- Reduced rework
- No pre-drilling
- Easy automation options
- Thinner materials (stress distribution)
- Design flexibility
- Fewer gaps and penetrations to seal – bond and seal simultaneously
- Eliminate corrosion
- Fatigue improvement due to not puncturing substrate
- Better aesthetic appearance
- Eliminate pull-through or drooping
- Damp sound and vibration
- Thermal expansion capability

Mechanical Fastener VS 3M™ VHB™ Tape

Surfaces
Materials
Joint Design

Adhesion: A Multidisciplinary Science

Definitions

- Adhesion
  - The physical attraction of the surface of one material for the surface of another
- Adhesive
  - Any substance that enables or enhances mechanical adhesion, usually between solids.
- Adherend
  - The material to which an adhesive displays adhesion
- Adhesive Bond or Adhesive Joint
  - The assembly made by the joining of adherends by an adhesive
- Practical Adhesion
  - The physical strength of an adhesive bond or an adhesive joint. Could be the force at which failure occurs of at which the adherend yields
- Cohesive Strength
  - The physical strength of a material
How Adhesives Work

- Adhesion: force between dissimilar materials
- Adhesive failure – at the interface (depends on mechanisms of adhesion)
- Cohesive failure – within the adhesive (depends on the adhesive)

Key Criteria for Adhesion

- Adhesive spreads well over the substrate ("wets out" the substrate)
- At some time during the bonding operation the adhesive should have a viscosity that is relatively low
- The adhesive and the adherend should be brought together in a rate and manner that should assist in the displacement of any trapped air

The adhesive needs to completely wet out the adherends

WetOut: Substrate Surface Energy (dynes)(mJ/m²)

Easy to adhere: Metal
- Copper 1103
- Anodized Al 170-500
- Kapton 50
- Polyester 43
- ABS 42
- Polycarbonate 42
- Acrylic 38

Hard to adhere: ESE
- PSA 37
- Polystyrene 36
- EVA 33
- Polyethylene 31
- Polypropylene 29
- PTF 28
- Teflon 18
WetOut: Clean Surface Needed

- Critical surface tension > 1000 mN/m
  - Adhesive wets out surface
  - GOOD BOND

- Critical surface tension < 30 mN/m
  - Adhesive "floats" on oil, does not contact aluminum
  - NO BOND

3 Contributors to Adhesion:

- Mechanical Adhesion
  - Right surface topography
- Diffusion theory
  - For plastics
- Adsorption theory

Mechanical Adhesion – why abrade

- Adhesive flows into surface irregularities
- Low viscosity (liquids and pastes)
- Heat (hot melts)
- Viscoelastic flow (PSAs)
- Mechanical interlocking especially with cured rigid adhesive
Adsorption Theory

- Chemical Interactions at the surface define adhesive forces

- Hierarchy of Bond Strengths
  - van der Waals
  - Dipole - Dipole Interactions
  - Polar Coordinate Bonds
  - Hydrogen Bonds
  - Ionic Bonds
  - Covalent Bonds

Increasing Chemical Force

Adhesive Joints Undergo Various Stresses

Goal: Minimize cleavage & peel, tensile & shear are better

There is always a mix of stress modes in real-world applications

Adhesive bond is pulled straight apart

Pull direction is across the adhesive, forcing the substrates to slide over each other

Concentrated pull at one edge, prying force

Other edge of joint is not stressed

Pull concentrates along a thin line at the edge of the bond where at least one substrate is flexible

Redesigning Joints for better Performance

Original design

Redesign
What we tested:
- Adhesive:
  - High Performing, Toughened 2 part Epoxy
- Substrates:
  - Bare Aluminum, solvent wipe only; Solvent wipe and abrade; Solvent/Abrade/Primer
  - Anodized No Seal, Anodized Hot Seal, Anodized Cold Seal
- Test:
  - Control (no aging); Modified Cataplasm aging (14 days at 70°C/100% RH followed by 1 day at -30°C and one day at 23°C/50% RH)

Can I bond Anodized?

WetOut –
Anodizing process leaves a surface free of contaminants
Aluminum Oxide is high surface energy

Mechanisms of Adhesion
Texture of Surface allows for Mechanical Interlocks
Chemistry allows for Adsorption

Conclusion: Anodized Surfaces should bond readily with Adhesives!

First Principles:

Epoxy Results
Conclusions:

Anodizing provides higher strength bonding with Epoxy than simply abrading bare Aluminum

Strength retention of Epoxy bond is very good

Anodizing provides a great surface for 3M™ VHB™ Tape Adhesion (PSA tape)

(previous testing)

OTHER types of Anodizing processes and colors not tested—work with your adhesive/tape supplier to request testing

• In particular, adding an organic colored finish may reduce bond strength with some products.
Panel to Frame – Attaching Glazing to Anodized Aluminum with 3M™ VHB™ Tape

Panel to Frame
Decorative or load bearing panel that is applied to rigid frame or support.
Examples:
- Trailer wall panels, elevator walls, curtain walls, glazing

What Are 3M™ VHB™ Tapes?
Aesthetics, flexibility and speed drive customers to tapes

- Double-sided, pressure-sensitive, acrylic adhesive foam tapes
- High-strength, UV & weather resistant adhesive for permanent bonding applications, both exterior & interior
- Replacement for liquid adhesives, welds, screws, rivets, and other mechanical fasteners
  - FLEXIBLE to allow for differential thermal expansion
- Adhesive for bonding a variety of materials, including metals, glass, plastics, composites, sealed wood, paints and powder coatings

3M™ VHB™ Structural Glazing Tape
Reference Project

San Diego International Airport
Terminal 2 Expansion
San Diego, CA
2012
Contract Glazier: Heineman Contract Glazing
Curtain Wall System: Iteltech Custom Wall
What Makes 3M™ VHB™ Tape Special?

Viscoelasticity
- The foam provides the strength
- The foam protects the bond

Bonds and Seals
- 100% closed cell

Durability
- All acrylic construction

Speed
- Immediate handling strength

Design Capability of 3M™ VHB™ Tape

The strength of 3M™ VHB™ Tape is dependent on the rate it is stressed because it is viscoelastic.

- Consider static forces
- Consider dynamic forces
- Consult with 3M

Glass Panel to Aluminum Frame Assembly – Structural Glazing and Commercial Window Applications

Structural Glazing & Commercial Window
- Curtain Wall
- Skylight / Canopy
- Operable Vent Windows
- Storefronts & Entrance Doors

Aluminum Extrusion Finish
- ≈ 40% Painted
- ≈ 60% Anodized (approx. 70% Clear anodized)

Glass Panels
- Insulated Glass Units (IGU)
- Laminated Glass

3M™ VHB™ Tape Structural Glazing

Structural Silicone Glazing

1 Bonding Component

2 Bonding Components

3M Adhesion Requirements for Structural Glazing Applications

- High bond strength >35 lbs/inch width (90º Peel, ASTM D3330)
- Cohesive failure

Painted Aluminum Finishes
- Polyvinylidene (PVDF) fluoride polymers (e.g., Kynar®, PPG Duranar®)
- Powder coats (Polyester, epoxy, PU)
- Clear coat anodized
  Primer or adhesion promoter required

Anodized Aluminum Finishes
- Clear Anodized
- Dark Anodized (e.g., Black, Dark Bronze)
  High bond strength typically achieved without the use of an adhesion promoter
### Glass Panel to Aluminum Frame Assembly – Surface Prep Considerations

<table>
<thead>
<tr>
<th>Substrate</th>
<th>IPA Clean</th>
<th>IPA + AP111</th>
<th>IPA + P94</th>
<th>Substrate Width (Y in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum Mullion (Clear Anodized)</td>
<td>23.2</td>
<td>22.0</td>
<td>21.3</td>
<td>5/8&quot;</td>
</tr>
<tr>
<td>Aluminum Glazing Interface (Kawneer, Silver Paint)</td>
<td>24.6</td>
<td>23.7</td>
<td>23.8</td>
<td>5/8&quot;</td>
</tr>
</tbody>
</table>

### Construction – Structural Glazing

- High strength, excellent UV resistance, fast/easy assembly
- Glass Panel Attachment
- Over 3000 buildings. First applications in Brazil 1990. Now in India, Mexico, Guatemala, Austria, others.

#### Structural wind load testing

- 3M™ VHB™ Taped panels performed similar to silicone glazed panels.
- Ache Laboratorio Farmaceutico Ltda.; Guarulhos, Sao Paulo, Brazil. Installed 1997
- Edificio Columbus; Santo Andre, Sao Paulo, Brazil. Installed 2002
- Structural wind load testing (Singapore, 2005):
  - 210 lb/ft² achieved with tempered glass.
  - With laminated glass, glass failed at 175 lb/ft². Glass fragments remained bonded to the tape.
  - Taped panels met 60 lb/ft² design requirement at ambient, cold (−13ºF) and hot (158ºF) temperatures.
- Acadaemia Paulista Anchieta – Uniban; Osasco, Sao Paulo, Brazil. Installed 2000
  - 3M™ VHB™ Taped panels performed similar to silicone glazed panels.

#### Mounting and Trim Attachment

- 3M Industrial Adhesives and Tapes.
What is Mounting and Trim?

Mounting:
Applying an object to a surface; generally static loads are prevalent and the mounted item is smaller than the surface to which it is bonded.
Examples:
Appliance skins, small signs

Trim:
Decoration or identification added to a surface
Examples:
Nameplates, edge banding, bezels, rosettes

Laminating Tapes

PSA Tapes Are used for Aesthetic Reasons and ease of Application

<table>
<thead>
<tr>
<th>PSA Tapes</th>
<th>Thin Double-Coated Tapes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adhesive Transfer Tapes</td>
<td>Release liner</td>
</tr>
<tr>
<td>Adhesive on a Removable Liner</td>
<td>Transfer tapes</td>
</tr>
<tr>
<td>- Thinner (1-5 mil)</td>
<td>- More conformable</td>
</tr>
<tr>
<td>- Higher temp. resistance</td>
<td>- Higher temp. resistance</td>
</tr>
<tr>
<td>- Doesn't interfere w/ flexibility of substrate</td>
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<tr>
<td>Adhesive on a Removable Liner</td>
<td>Thin Double-Coated Tapes</td>
</tr>
<tr>
<td>Adhesive on Both Sides</td>
<td>Release liner</td>
</tr>
<tr>
<td>Tape with a Carrier and Adhesive on Both Sides</td>
<td>Transfer tapes</td>
</tr>
<tr>
<td>- Thicker (3-10 mil)</td>
<td>- More body to the tape</td>
</tr>
<tr>
<td>- Easier dispensing (more body to the tape)</td>
<td>- Lower temp. resistance</td>
</tr>
<tr>
<td>- Doesn't interfere w/ flexibility of substrate</td>
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</tr>
<tr>
<td>- A wide range of internal carriers are available</td>
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</tr>
</tbody>
</table>

Reclosable Fasteners

Aesthetics are better; tools not needed to attach/detach; substrate not compromised

<table>
<thead>
<tr>
<th>Dual Lock</th>
<th>Hook &amp; Loop</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Holes Required</td>
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</tr>
<tr>
<td>- Reduce Potential Corrosion &amp; Leaks</td>
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</tr>
<tr>
<td>- Better aesthetics: no nails, screws or bolts</td>
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</tr>
<tr>
<td>- Quick and Easy Opens and Closures</td>
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</tr>
<tr>
<td>High Performance Adhesives</td>
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</tr>
<tr>
<td>- Ability to bond to wide range of surfaces</td>
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</tr>
<tr>
<td>- Ability to resist environmental factors</td>
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</table>
Mounting and Trim – Electronics, Appliances

Applications
• SN Labeling
• Nameplates
• Bezels
• Skins
• Spacer Attachment

Mounting and Trim – Electronics, Appliances

Applications
• Bumpers and Stops
• Skid Plates
• Lens Attachment
• Keypad Attachment

Transportation

• 3M™ VHB™ Adhesive Transfer Tape bonding stainless steel to aluminum, tolerates -65°F to 150°F with no other fastener used.

3M™ VHB™ Tape has been used to bond the anti-chaffing strip to the aircraft wing since 1984.

Small Joint Assembly
What is Small Joint Assembly?

Small joints are found everywhere!
Small joints are typically irregularly shaped but only a few inches of overlap area and high stress on the joint. They may be insertion joints or overlap joints, or some combination.

Examples: Sporting goods (e.g., golf club heads to shaft), plastic casings, lens mounting for instrumentation, mortise and tenon furniture joints, thread locking or shaft retaining, magnet bonding, jewelry making.

Structural Adhesives

Allow dissimilar material bonding; better fatigue and strength with stress distribution; better aesthetics without finishing

- One part and two part (“epoxies”) curing adhesives
- Highest load bearing strength
- Best environmental resistance

Multiple chemistries incl.:
• Epoxies
• Acrylics
• Urethanes
• Cyanoacrylates (instant)
• Anaerobics (threadlockers)

Sporting Goods

Applications:
• Anodized Bicycle parts
• Anodized tubes to grips or frames
• Racquets
Applications:
• Cover Assembly
• Box Build
• Tacking and Attaching
• Lens housings and mounting rings
• Speakers, mics…

Applications:
• Rubber endcaps
• Box Build – hinges, dividers…
• Miscellaneous small parts – metal to plastic, etc.
• Anodized aluminum parts for spacecraft/aerospace

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