Achieving Adhesion to Difficult Metal and Plastic Substrates

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Agenda

- Types of Adhesion
- Routes to Modifying Adhesion
- Focus on Chemical Adhesion
- Summary

UV/EB Coatings

Advantages

- Low/no VOC
- Reduced energy costs
- Shorter cure time
- Space savings
- Hardness, scratch resistance, chemical resistance

Challenges

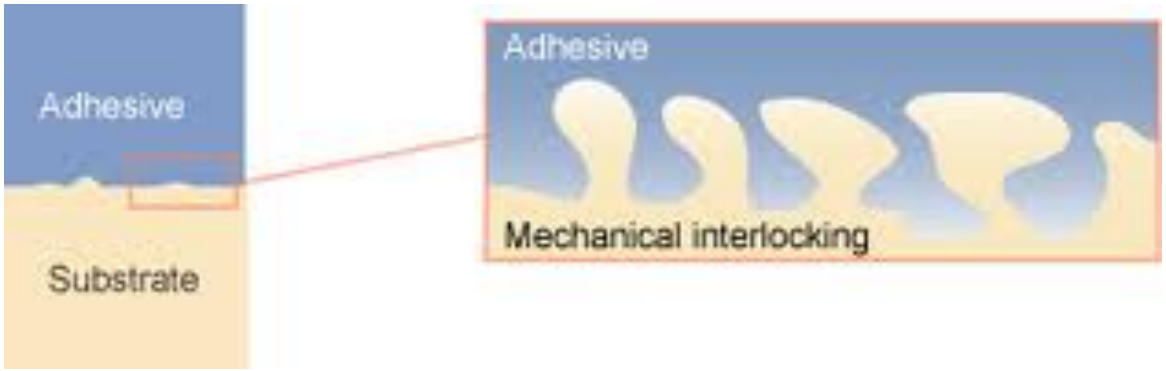
- Adhesion to difficult substrates
- Spray application for coating post-formed items
- Corrosion (salt spray) resistance
- Pigmentation (UV at higher coating thickness)

Types of Adhesion

- Mechanical bonding
- Chemical bonding
- Electrostatic
- Dispersive
- Diffusive

Routes to Modifying Adhesion

Mechanical adhesion: A form of adhesive bonding during which adhesive material physically locks into the crevices of the surface.



- Increase roughness by abrading surface
- Chemically etch the surface
- Swell substrate to promote penetration of coating (Plastics)

Routes to Modifying Adhesion

Substrate wetting: The replacement of adherent air at the substrate surface by a liquid coating or ink material.

- Ideal: Substrate surface energy > coating surface tension
- Metals tend to have higher surface energy

- Increase surface energy
  - Clean oils, grease

- Decrease surface tension
  - Choice of monomer
  - Additives

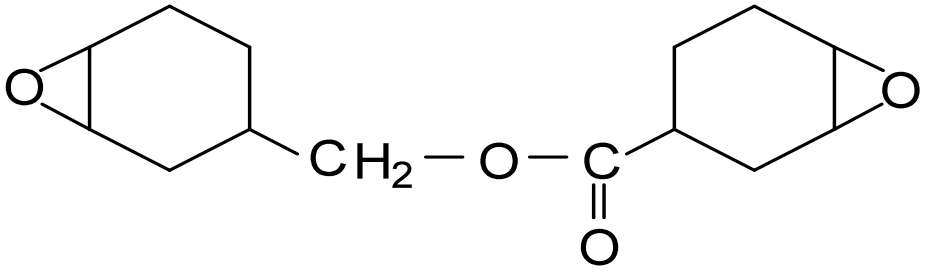
Routes to Modifying Adhesion

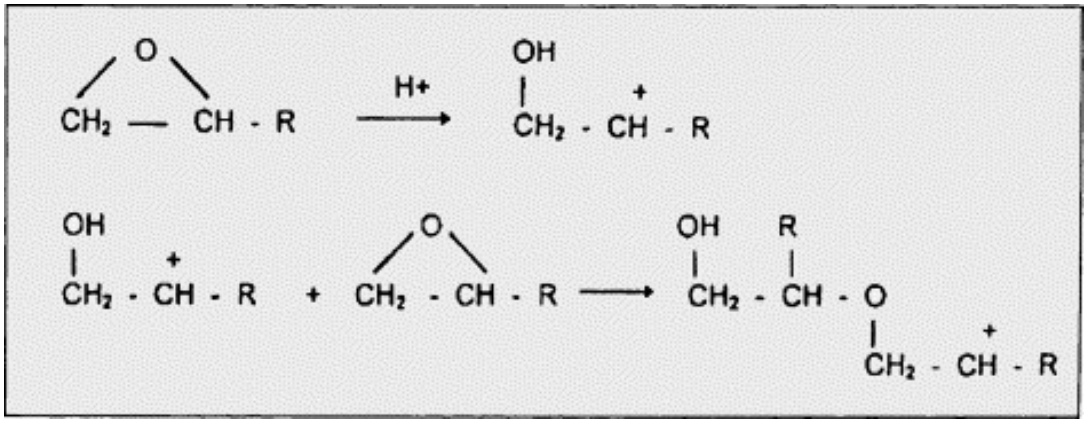
Chemical adhesion: The coating chemically bonds with groups on the surface of the substrate.

- Use coupling agents
  - Reaction with substrate (e.g. silane acrylates)
- Intercoat adhesion
  - Under cure primer coat (residual acrylate groups)
  - Dual cure (e.g. acid/epoxy)
- Change the base chemistry
  - Cationic Cure
- Use polar groups
  - H-bonding

UV Cationic Curing

- **Cycloaliphatic Epoxide(s)**
  basic coating properties





Routes to Modifying Adhesion

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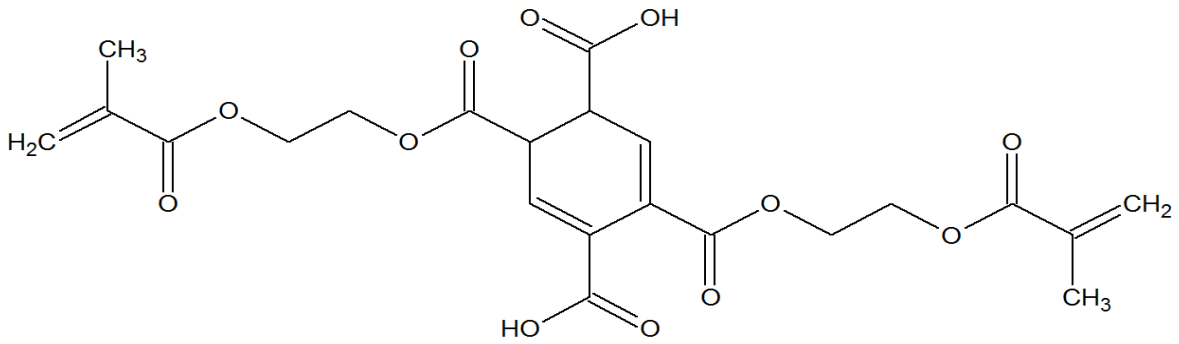
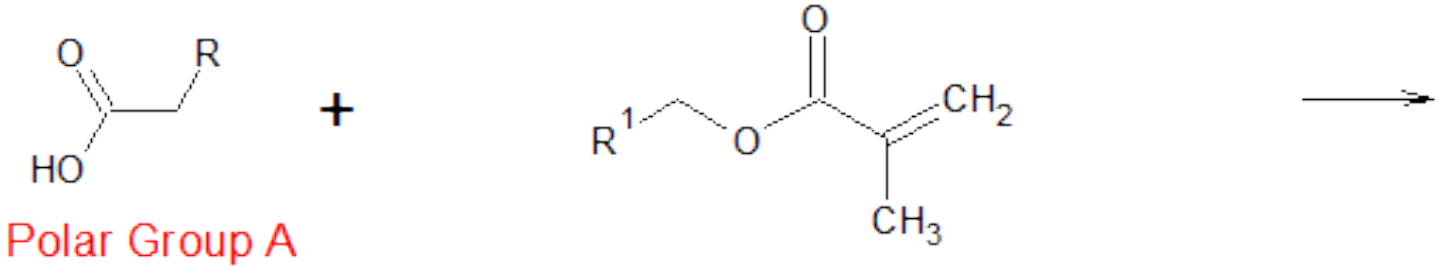
- Change the base chemistry
  - Cationic Cure
- **Use polar groups**
  - **H-bonding**

Typical Dental Adhesive Monomers

- High Performance
- Challenging Substrates
- High Quality Requirements

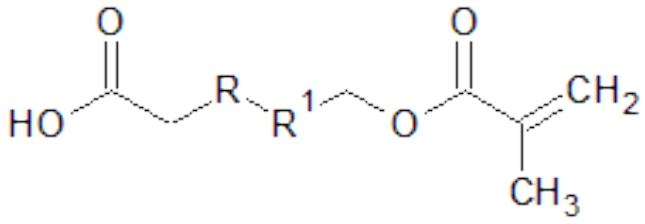


Approach to New Adhesion Modifiers



Polar Group A

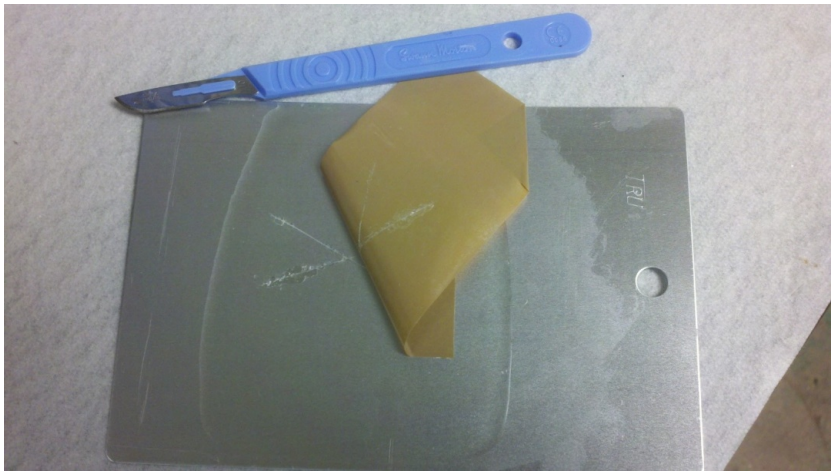
(Meth)Acrylate B



Adhesion Promoter C

ASTM Method D3359 – 09

- Standard Test Methods for Measuring Adhesion by Tape Test
  - Apply formulation on substrate using a draw down bar.
  - UV cure using a Sunray 600 UV Flood Lamp with a 400W bulb
  - X-cut is made through the film to the substrate
  - pressure-sensitive tape (TESA 4124) is applied over the cut and then removed
  - adhesion is assessed qualitatively on the 0 to 5 scale



Metal Adhesion Results

Product	Aluminum	CRS	Stainless Steel
PL-2110 (A)	4A	4A	4A
PL-2122 (L)	5A	5A	5A
PL-2236 (N)	5A	5A	5A
PL-2179 (Q)	2A	1A	3A
PL-2155 (R)	4A	4A	4A
PL-2263 (O)	5A	5A	5A
PL-2317 (G)	1A	0A	1A
PL-2212 (M)	5A	5A	5A
PL-2349 (S)	5A	5A	5A

Metal Adhesion Results

Product	Tin Covered Steel	Tin Free Steel	Copper
A	0A	0A	0A
L	5A	*	5A
N	1A	5A	5A
Q	0A	*	1A
R	2A	4A	4A
O	0A	5A	5A
G	0A	0A	0A
M	5A	*	5A
S	4A	5A	5A

* - Difficult to wet out, test results not valid

Plastic Adhesion Results

Product	PVC	PET	Polycarbonate
A	5A	3A	*
L	0A	3A	0A
M	0A	5A	*
R	0A	3A	0A
O	0A	5A	0A
Q	0A	3A	0A
N	0A	5A	1A
G	5A	1A	5A

* - Difficult to wet out, test results not valid

Acrylate vs. Methacrylate

Product	PVC	PET	Polycarbonate
A	5A	3A	*
L	0A	3A	0A
M	0A	5A	*
R	0A	3A	0A
O	0A	5A	0A
Q	0A	3A	0A
N	0A	5A	1A
G	5A	1A	5A

* - Difficult to wet out, test results not valid

L= Methacrylate, M = Acrylate with same polar group (A)

R= Methacrylate, O = Acrylate with same polar group (A)

Plastic Adhesion Results

Product	ABS	PMMA	Nylon 6/6
A	4A	0A	5A
L	0A	4A	2A
M	0A	0A	0A
R	0A	3A	3A
O	0A	0A	4A
Q	4A	4A	3A
N	5A	2A	5A
G	5A	3A	0A

* - Difficult to wet out, test results not valid

Acrylate vs. Methacrylate

Product	ABS	PMMA	Nylon 6/6
A	4A	0A	5A
L	0A	4A	2A
M	0A	0A	0A
R	0A	3A	3A
O	0A	0A	4A
Q	4A	4A	3A
N	5A	2A	5A
G	5A	3A	0A

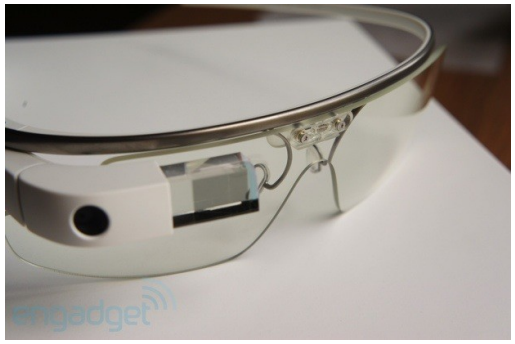
* - Difficult to wet out, test results not valid

L= Methacrylate, M = Acrylate with same polar group (A)

R= Methacrylate, O = Acrylate with same polar group (A)

Adhesion to Glass

Product	Adhesion Results
A	4A
L	5A
M	5A
R	4A
O	5A
Q	1A
N	5A



Improving Adhesion in Formulations

% Adhesive Promoter	Aluminum	CRS	Stainless Steel	Tin Free Steel	Copper
0	0A	0A	0A	0A	0A
2	3A	1A	0A	0A	0A
5	3A	3A	0A	1A	0A
8	3A	3A	2A	1A	1A
10	5A	5A	3A	3A	2A

Base Resin: Aliphatic Urethane Diacrylate Exothane 26
Adhesion Promoter: PL-2121
PI: 3% PL-460

Improving Adhesion in Formulations

% Adhesive Promoter	PET	Polycarbonate	Nylon 6/6	ABS	PMMA	Glass
0	5A	3A	0A	1A	0A	0A
2	5A	3A	0A	1A	0A	0A
5	5A	3A	0A	2A	0A	0A
8	5A	4A	0A	3A	1A	1A
10	5A	5A	0A	5A	1A	1A

Base Resin: Aliphatic Urethane Diacrylate Exothane 26
Adhesion Promoter: PL-2121
PI: 3% PL-460

Approaches to Getting Adhesion

- Pretreatment:
  - Surface cleaning
  - Surface abrasion/roughening
- Wetting agents
  - Surface energy of substrate 5-10 dynes/cm > than coating
- Primer
- Minimize shrinkage upon curing
- Use reactive, polar monomers

Thank You

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