UV Adhesives for Automotive and Electronic Applications & Benefits of Surface Treatment

Brian Betty
DELO Industrial Adhesives LLC
Regional Sales Manager

Jeff Leighty
Plasmatreat USA Inc.
Sales & Business Development Manager

The Case for Light-Curing Adhesives

Why bond with light-curing adhesives?

- Rapid curing possible (below 1sec)
- Well-suited joining technology for hybrid and plastic bonding
- No thermal stress on components
- Precise control of the curing ("curing on demand")
- In-line process possible
- Ideally suited for high degree of automation in production

Light-curing adhesives enable fully automated electronic manufacturing
The Challenges of Light-Curing Adhesives

What needs to be considered when bonding with light-curing adhesives?

- Rapid curing narrows the process window
- Some hybrid and plastic substrates are difficult to bond to
- Requires precise control of the curing (“curing on demand”)
- Line of sight for some (e.g. free-radical) chemistries
- High crosslink density changes the process latitude

Plasmatreat – At a Glance

- More than 20 years of experience
- Currently 150 employees
- Over 5,000 installed systems
- Over 10,000 installed jets
- 3 North American Offices: Elgin, IL (HQ), California, and Ontario, Canada
DELO – At a Glance

- More than 50 years of experience
- Currently 350 employees
- Sales revenues: EUR 52 million
- Investment in R&D: 15 % of sales revenues
- 30 % of revenues with products less than 3 years old

What is an adhesive

DIN EN 923: An adhesive is a non-metal that connects two components through adhesion and cohesion.

Physical adhesive forces

Physical cohesive forces

Component 1

Foreign matter on component (such as contaminants, greases, oils, etc.)

Crystalline structure

Component 2

No wetting due to too narrow recess

Chemical adhesive forces

Chemical cohesive forces
Adhesive types

Adhesives differ in their curing process, dispensing or in their chemical basis. A universal adhesive does not exist.

<table>
<thead>
<tr>
<th>Physically setting</th>
<th>Chemically curing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot melts</td>
<td></td>
</tr>
<tr>
<td>Solvent adhesives</td>
<td></td>
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<tr>
<td>Dispersion adhesives</td>
<td></td>
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<tr>
<td>Pressure-sensitive adhesives</td>
<td></td>
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<tr>
<td>Plastisols</td>
<td></td>
</tr>
<tr>
<td><strong>Polymerization:</strong> Light- and UV-curing acrylates and epoxy resins</td>
<td>Polyaddition: 1C epoxy resins 2C epoxy resins 1C polyurethanes 2C polyurethanes 2C silicones</td>
</tr>
<tr>
<td>Cyanocrylates</td>
<td></td>
</tr>
<tr>
<td>Anaerobic-curing adhesives</td>
<td>Polycondensation: 1C silicones 1C silicones (heat-curing) 2C silicones Silane-mod. polymers Phenolic resins Polyimides</td>
</tr>
<tr>
<td>Methyl methacrylates</td>
<td>Unsaturated polyester</td>
</tr>
</tbody>
</table>

2 main groups: Epoxies and acrylates

<table>
<thead>
<tr>
<th>Basic resin</th>
<th>Epoxy</th>
<th>Acrylate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Curing of shadowed areas</strong></td>
<td>Dual curing (light-heat-curing) Preactivation</td>
<td>Dual curing light-heat-curing Dual curing light-humidity-curing</td>
</tr>
<tr>
<td><strong>Strong points</strong></td>
<td>Thermal resistance Chemical resistance Low outgassing Optically clear Yellowing-resistant High barrier effect towards water Reflow stability</td>
<td>Extremely fast curing High equalization of tensions High peel resistance Optically clear Universally good adhesion</td>
</tr>
<tr>
<td><strong>Typical application areas</strong></td>
<td>Semiconductor packaging, bonding/sealing in the automotive industry, optoelectronics, organic electronics, display encapsulation</td>
<td>Consumer electronics, glass bonding, medical accessories, display bonding</td>
</tr>
</tbody>
</table>
Advantages of UV bonding

**Thermal**
- No negative heat influence on the structure (embrittlement, melting)
- No component distortion

**Material**
- Versatile combinations possible
- Heat-sensitive materials can be used
- Electro-chemically dissimilar materials possible

**Design**
- Component thickness not important
- Complex geometry possible

**Process**
- Large surfaces in one process step
- Easy to automate

Light Spectrum

Light is the part of the electromagnetic spectrum visible to the human eye, and the neighboring ranges of ultraviolet (UV) and infrared (IR) light.
Energy vs. Penetration Depth

Depending on the property investigated, light behaves as wave or particle (dualism). A certain energy can be assigned to every light particle (quant), depending on its wavelength:

\[ E = h \cdot \nu = h \cdot \frac{c}{\lambda} \]

- \( E \): Energy
- \( h \): Planck's quantum of action
- \( \nu \): Frequency
- \( c \): Light speed
- \( \lambda \): Wavelength

In technical terms, small energy units can be transferred to molecules of photoinitiators by light. When exceeding a minimum energy, these are split by the light quant and can initiate polymerization.

Emissions and absorption spectrum

**Emission spectrum**

Most light sources emit light of dissimilar wavelengths. In most cases, the intensity (quants per time unit) also depends on the wavelength. This is called the emission spectrum of the light source.

**Absorption spectrum**

Photoinitiators absorb light or energy at various wavelengths to a varying extent. Below a threshold energy (above a wavelength), they cannot absorb any light anymore. An absorption spectrum is created.
Adjustment light – photoinitiator

If there are light-absorbing layers between the adhesive and the light source, it is possible that the spectral range necessary for adhesive curing is completely screened off.

As a consequence, the permeability of the layers must be considered when selecting the light source and the photoinitiator.

Transmission of plastics

Plastics can differ widely in their light permeability. Even within a material group, there may be strong differences. Therefore, the transmission of the substrate must be considered when selecting lamp and adhesive.
Options for processing

**Light- or UV-curing**

- Dispensing
- Joining
- Curing

**Activated by light**

- Dispensing
- Activating
- Joining and curing without further irradiation

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**Pre-activation**

A) **Dispensing**

The adhesive is dispensed onto the component. The dispensing system must be shielded from bright light with wavelengths ranging from 400 to 550 nm. → First, the adhesive remains liquid!

B) **Preactivation**

The adhesive is preactivated with visible light (400 – 550 nm), duration between 1 – 30 s.

C) **Joining**

After irradiation, a thin skin is formed on the adhesive after a period of time called "open time". The components must be joined within the open time, i.e. before skin is formed on the adhesive.

D) **Complete curing**

After joining, the entire preactivated adhesive volume cures without further irradiation. By irradiating the fillet afterwards, fast fixation can be achieved. Heat supply accelerates curing.
Dual curing with Humidity

What about electronic components with shadowed/boundary areas?

Main concern:
- Liquid & uncured adhesive inside electronic components (e.g. corrosion could occur)

Solution: UV/VIS light + humidity curing adhesives
- Dual curing allow fast curing by UV or VIS light
- In shadowed areas, the adhesives cures by ambient humidity
- Curing speed by humidity ≈ 2 mm / day (acceleration with heat possible)
- Isocyanate & silicone-free

Light for fast fixing – humidity for safe curing in shadowed areas

Dual curing with Heat

Sealing and casting in the (automotive) assembly industry

Advantages:
- Short cycle times
- Good adhesion to metal pins and plastic components
- Soldering resistance
- High flexibility is possible
- Reliable curing in shadowed areas
- Curing with heat (minimum 80 °C) or humidity
  - Fast curing of visible areas with light
- Temperature range of use up to 150 °C
- Tension-equalizing with an elongation at tear up to 50 %
- Fast heat-curing – e.g. 3 min at 130 °C
### Difference LED lamp / discharge lamp

<table>
<thead>
<tr>
<th></th>
<th>LED lamp</th>
<th>Discharge lamp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>Discrete, narrow distribution around peak wavelength</td>
<td>Continuous, broad spectrum with local peaks</td>
</tr>
<tr>
<td>Heat development</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Lifetime</td>
<td>At least 10,000 h, typically &gt; 20,000 h</td>
<td>Bulb: 1,000 – 2,000 h</td>
</tr>
<tr>
<td></td>
<td>Lifetime = &quot;on&quot; time</td>
<td>Lifetime = process runtime</td>
</tr>
<tr>
<td>Intensity decrease</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Current consumption</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Costs</td>
<td>One-time investment in LED lamp, energy</td>
<td>One-time investment in discharge lamp, spare bulbs, energy</td>
</tr>
<tr>
<td>Intensity setting</td>
<td>Electronically settable</td>
<td>Change of distance</td>
</tr>
</tbody>
</table>

### Challenges of Light Curing

Reactive adhesives require complete and reproducible curing for an optimal function.

In the case of light-curing adhesives, curing may be impaired by the following factors:

- Shadowed areas
- Too short irradiation time
- Too low lamp intensity
- Poorly transmittable substrates
- Too thick adhesive layer
- Insufficient coordination of lamp spectrum / photoinitiator
- Inhibition

Knowledge and safeguarding of the correct curing state are key factors or process reliability! Of course, further factors, including surface quality and dispensing quantities must also be considered.
Process Verification

- Curing of adhesives
- Curing control
  - Measuring of the chemical implementation
    - Structure of functional groups
    - Residual reactivity
  - Measuring of adhesive properties
    - Mechanical properties
    - Thermo-dynamic properties
    - Spectroscopic properties
  - Measuring of the bonded connection

The problem of adhesion

Inks, coatings, adhesives, and sealants fail when surface contamination or low surface energy prevents adequate adhesion.
The problem of adhesion

Getting things to stick properly requires some kind of reformulation to the chemistry, change of substrate, or more commonly, surface treatment.

The need for surface preparation?

- **STATIC REMOVAL**: Static attracts dust and similar contaminants which interfere with surface processes.

- **CLEANING**: All surfaces, no matter how clean they seem, have surface contaminants that interfere with bonding and coating applications.

- **ACTIVATION**: Advanced engineering polymers tend to be chemically inert – with few or no functional groups on which to bond.

- **PASSIVATION**: Metals are prone to oxidation and require treatment to retard the oxidation process.
So, how do you choose?

- Efficiency
- Speed
- Flexibility
- Safe
- Green
- Cost efficient

Why Plasma?

A good fit for UV processing

The environmental benefits of atmospheric plasma are a good fit for UV technology

- Elimination of high VOC content primers or adhesive promoters – replace these with environmentally safe plasma
  
- Low power consumption
- No ozone generation
- No pollutants

Courtesy Texas A&M University
Contamination: External Causes:

- Oil
- Dust
- Grease
- Fingerprints

Contamination: Internal Causes:

- Anti-oxidants
- Cross-linkers
- Fillers
- Pigments
- Slip Agents, Waxes
- UV Modifiers
Atmospheric plasma treatment

- **What is plasma?**
  - How is plasma generated and applied
- **Functions of plasma treatment**
  - Cleaning of glass, plastics, metals, ceramics
  - Functionalization of ceran and galvanized steel
  - Activation of polypropylene and GFRP
Plasma is the 4th state of matter.

Plasma
- gas molecule
- gas molecule (excited)
- ion
- free electron
- molecule fragment (high-energy)

How plasma works

- Ionization Gas
- Inner Electrode
- Ring Electrode (SS casing)
- Discharge Chamber
- High voltage Current
- Plasma Beam
- Substrate
The plasma process

Surface Contamination
- Static charged surface (with dust particles)
- Organic layers (additives, waxes, grease....)

Polymer Substrate
- OPP, PE, PET, Acetate....
- UV varnish

Anti Static Effect
- Attack electrostatic charge
- Remove dust particles

Surface Contamination
- Organic layers (Additives, waxes, grease....)

Polymer Substrate
- UV varnish
- OPP, PE, PET, Acetate....
The plasma process

**Cleaning effect**

Remove surface contamination

Surface contamination

Polymer Substrate
OPP, PE, PET, Acetate, ... UV varnish

The plasma process

Form functional sites

Carbonyl Groups

Hydroxyl Groups

Polymer Substrate
OPP, PE, PET, Acetate, ... UV varnish

Stable wetting
Plasma surface treatment effects

Topological Modification (AFM Study of PET [1 µm])

Atmospheric Pressure Plasma Process - Activation

PP: untreated
(surface free energy: 27.0 mN/m)

PP: Openair™ Plasma treated
(surface free energy: up to 72 mN/m)
Plasma surface treatment effects

Surface Energy of Polypropylene After Plasma Treatment

Plasma surface treatment results

2-part epoxy system:
Curing: 175°F, 2 hours
Substrate Flexibility

Substrates
- Plastics
- Metal
- Glass
- Ceramics
- Mixed Materials
  → Ceran
  → CFRP
  → GFRP

Flexibility for many applications

A wide selection of standard and custom jets adapt to a wide range of part shapes and sizes..
Atmospheric plasma generators are easy to install and integrate with simple connections.

Automotive and Electronics Applications

**Automotive Headlamp Treatment**

**Populated Circuit Board Application**
Summary:

Plasma:
- Cleans
- Activates

Prior to:
- Sealing
- Bonding

On:
- Plastics
- Glass
- Metal
- Ceramics

Wettability

Good wetting is a necessary criterion for good adhesion. For sufficient adhesion, the adhesive must be able to cover a sufficiently large area.

- Wetting angle $\alpha$ is small
- Surface tension $\sigma_{\text{substrate}} > \sigma_{\text{adhesive}}$
- Adhesion work $>$ cohesion work

- Wetting angle $\alpha$ is large
- Surface tension $\sigma_{\text{substrate}} < \sigma_{\text{adhesive}}$
- Adhesion work $<$ cohesion work
Summary:

- UV Curing offers many advantages in speed, low temperature processing, increased performance and safety & Environmental compliance for adhesive sealing and bonding, but the technology also poses some unique challenges.

- Some of these challenges require attention to surface preparation to achieve adequate bonding to difficult substrates.

- Plasma surface treatment offers UV applicators a similarly fast, low temperature, safe and environmentally compliant technology.

- The results are increased adhesive performance in a wide range of automotive and electronics adhesive applications.
Follow Up:

Thank you to Radtech

To learn more about UV adhesives, attend:

Contact Information:

Brian Betty  
Regional Sales Manager

DELO Industrial Adhesives  
144 North Road, Suite 2650  
Sudbury, MA 01776  
Office: 978 341 4602  
Cell: 978 760 5346  
[Email] [Website]

Jeff Leighty  
Sales & Business Development Manager

Plasmatreat US  
2541 Technology Drive, Suite 407  
Elgin, IL 60124  
Office 847.783.0622 Ext. 2121  
Mobile 847.840.9960  
[Email] [Website]