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# Goldilocks and Process Control for UV Curable PSAs

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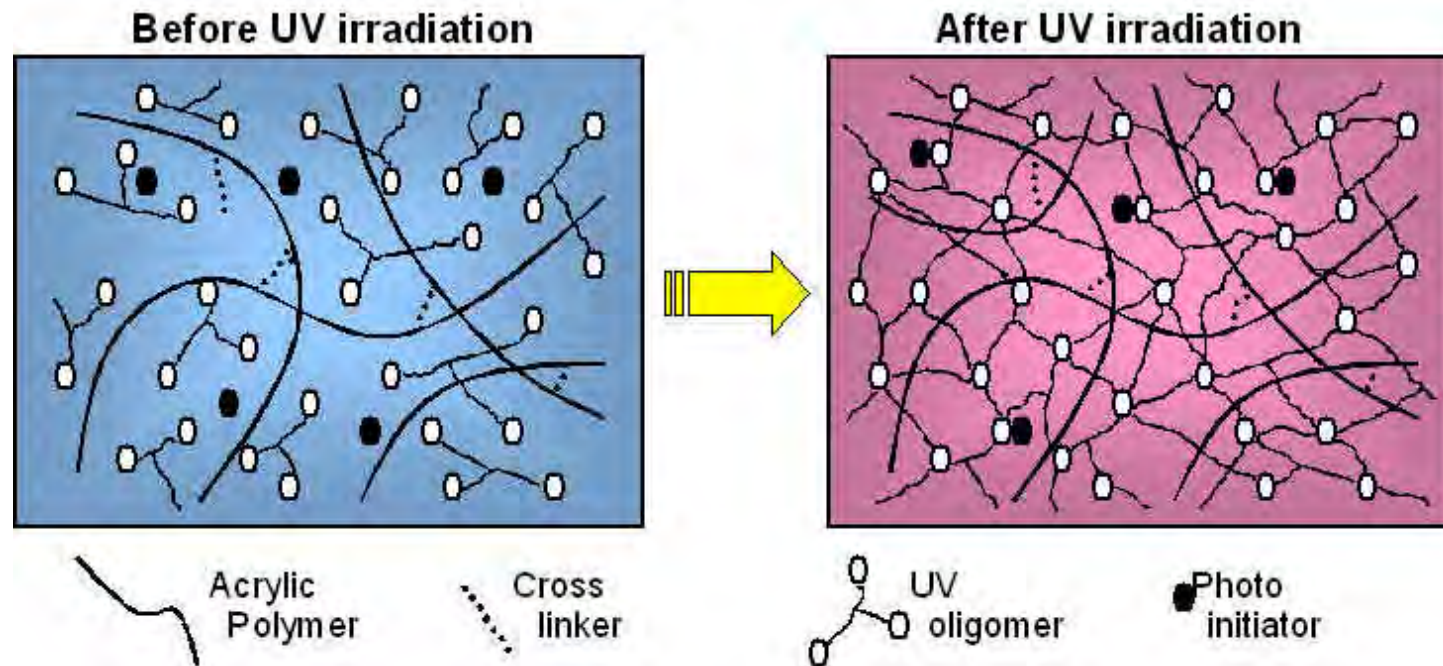


# Motivation





# The UV process





# The importance of proper UV cure

Setting and maintaining proper UV exposure is always important.

However, with UV PSAs it is even more important since you can not only under-cure material, but can over-cure material as well.

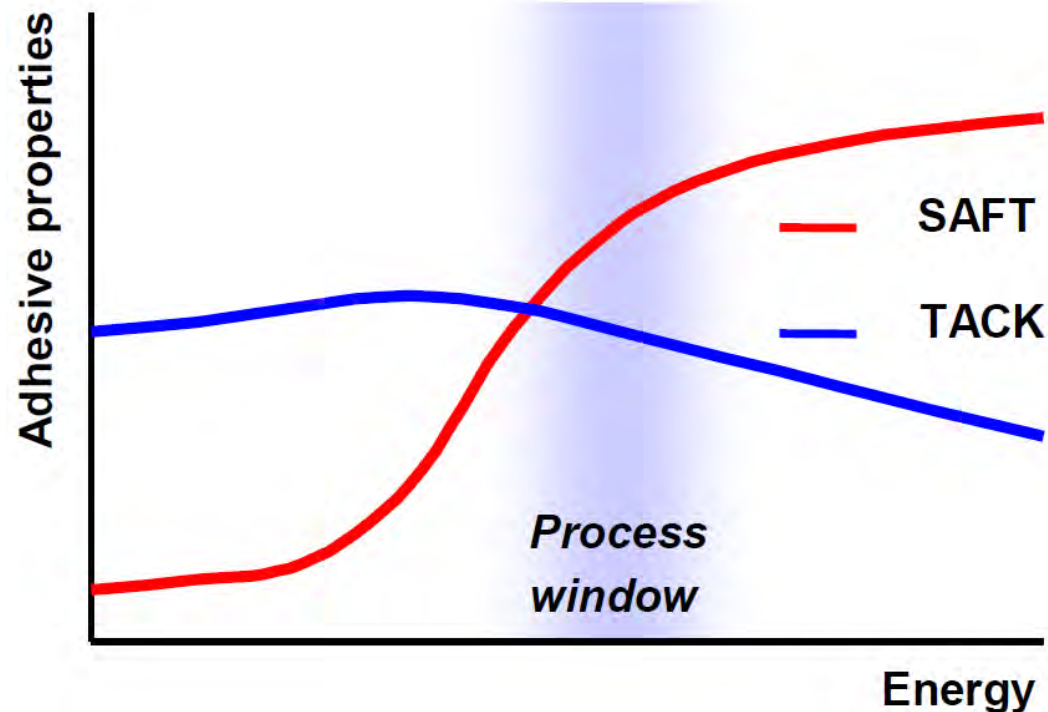




# Motivation

The “Process Window” for curing UV reactive PSAs can be relatively narrow; adhesive properties can change significantly with both too little, and, too much UV energy.

Petra Burger, Fusion UV, *UV Curable Pressure Sensitive Adhesives*

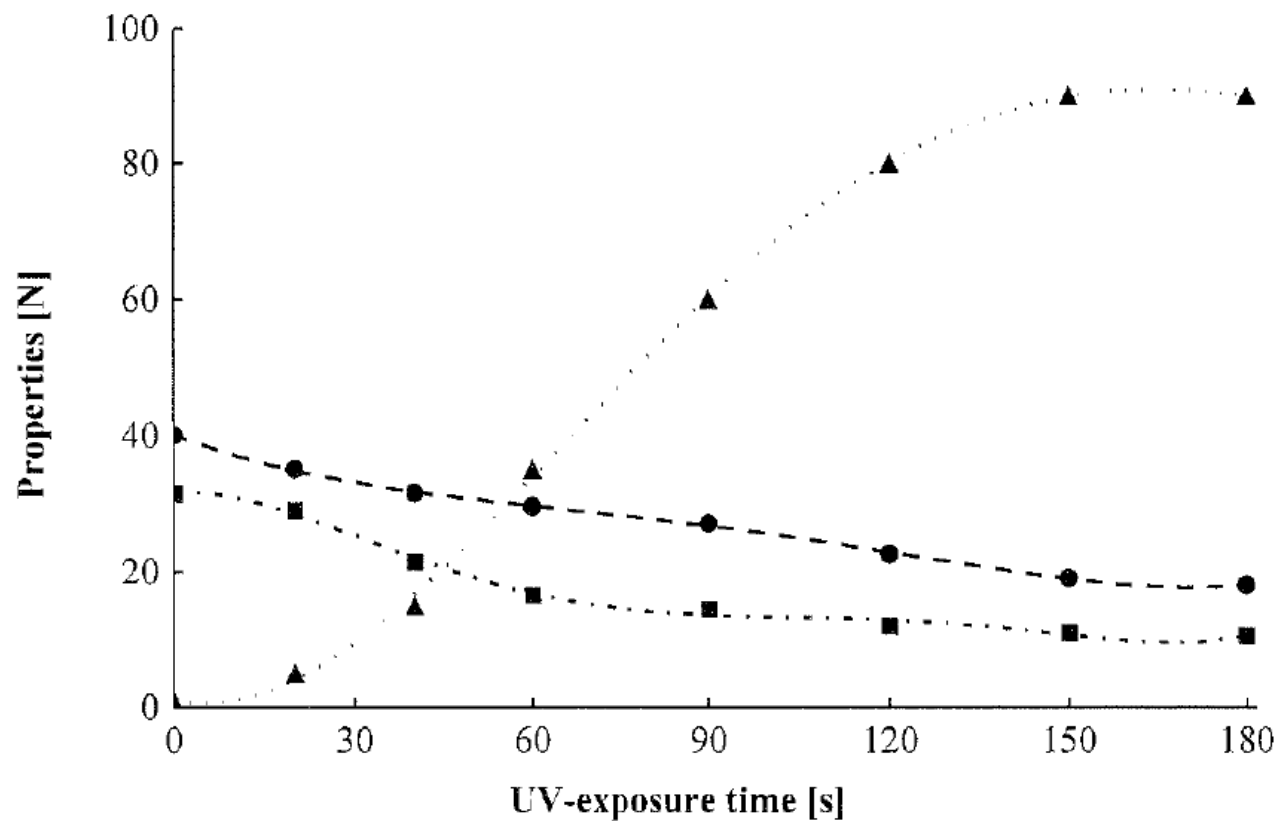






# Motivation

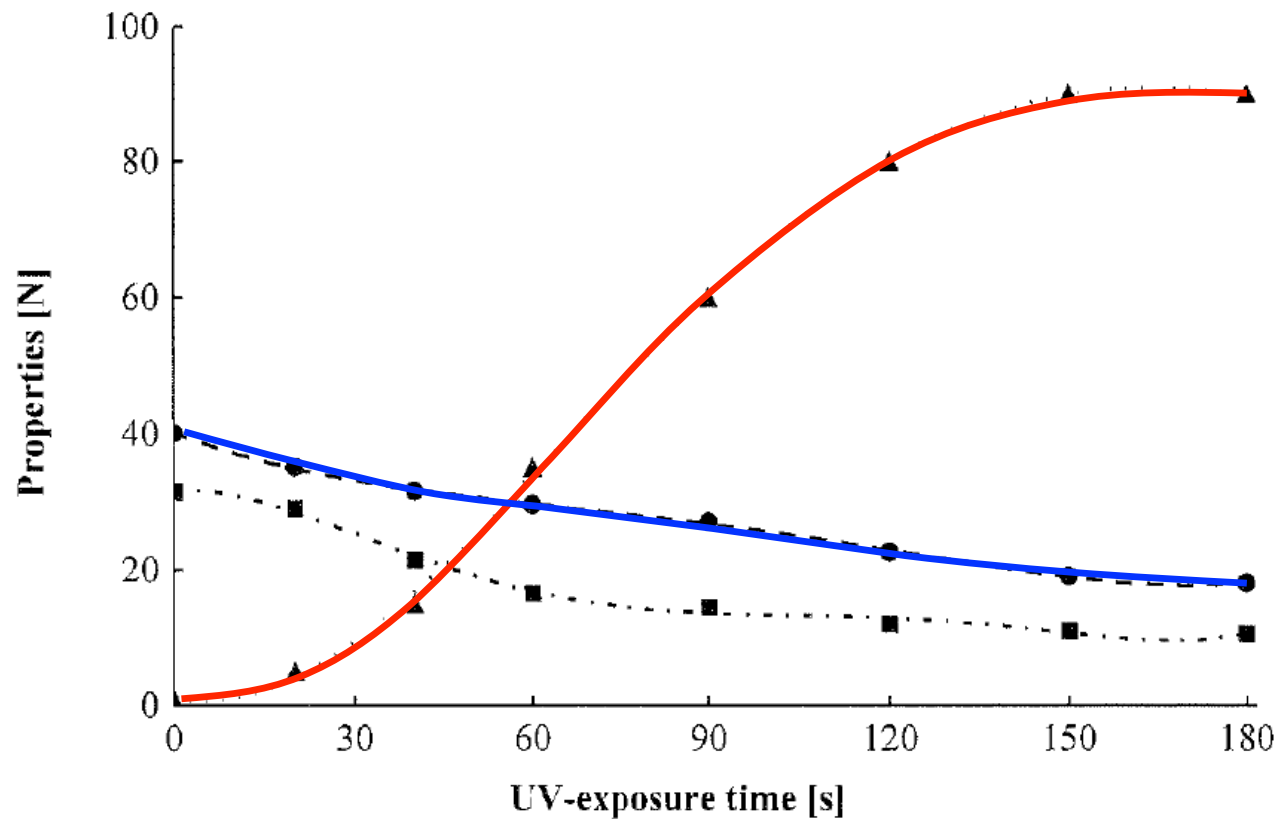
Influence of UV-crosslinking time on tack (●), peel adhesion (■) and cohesion (▲). (Czech 2004)





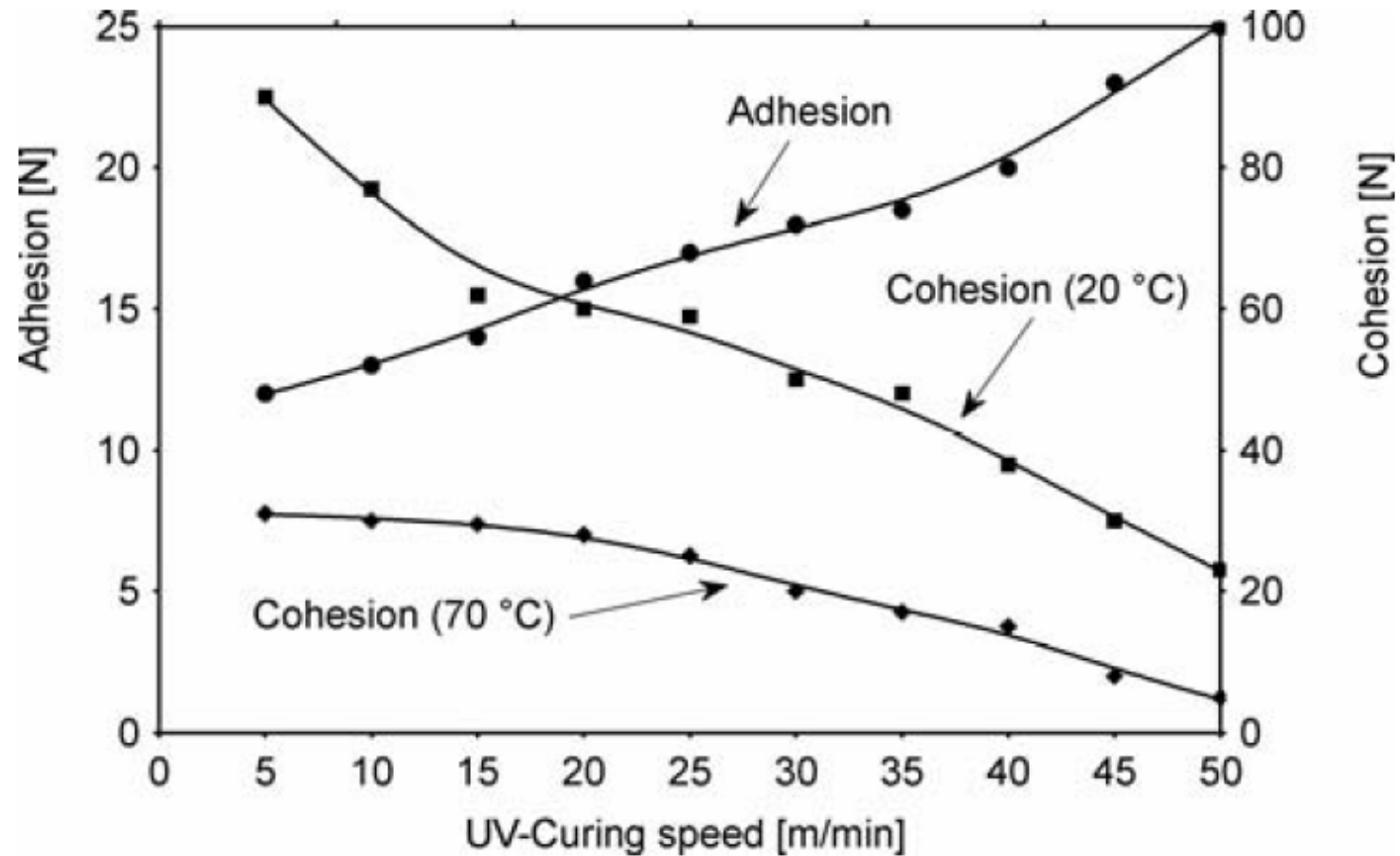
# Motivation

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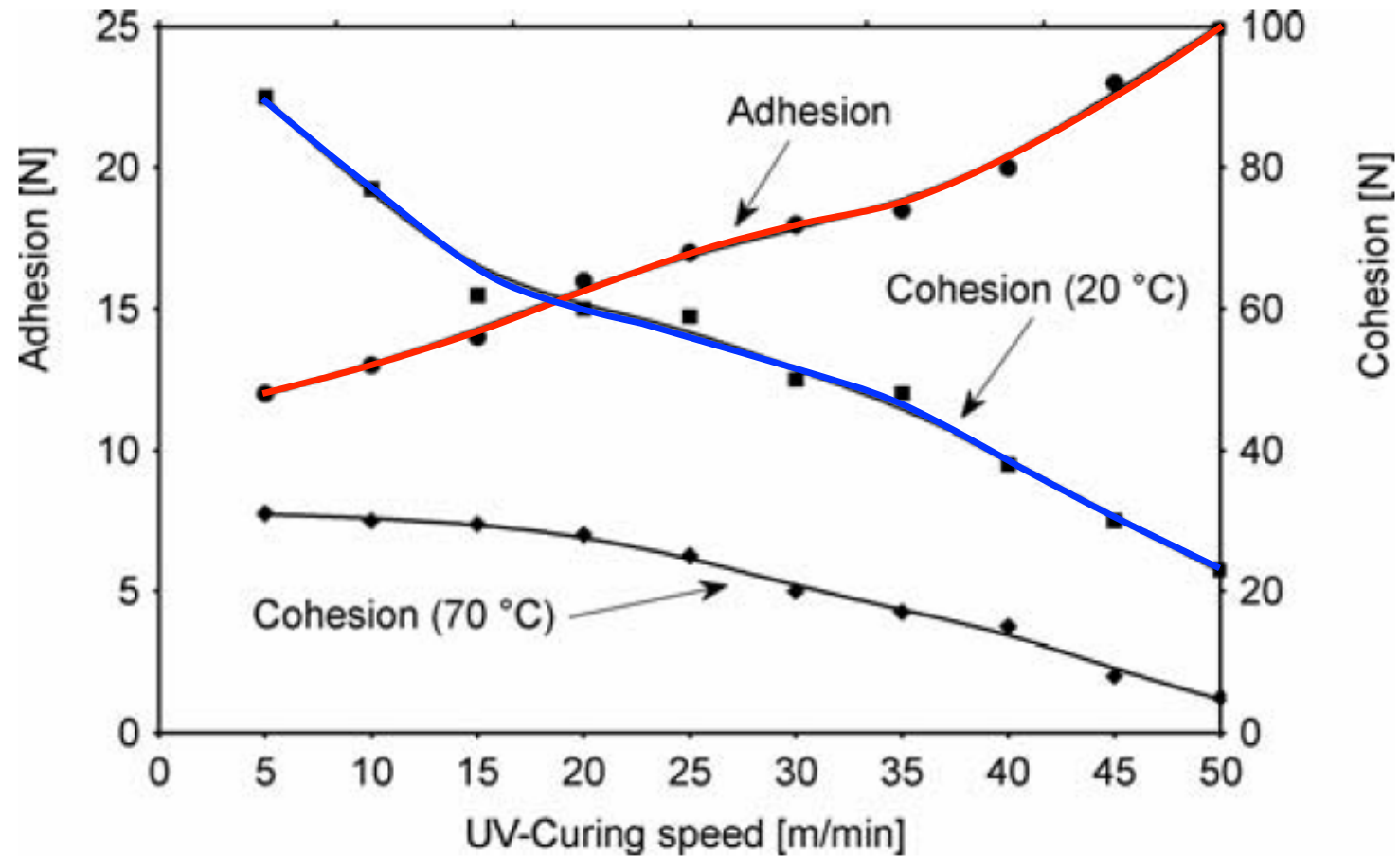
# A Balancing Act







# A Balancing Act





# The Goldilocks Problem

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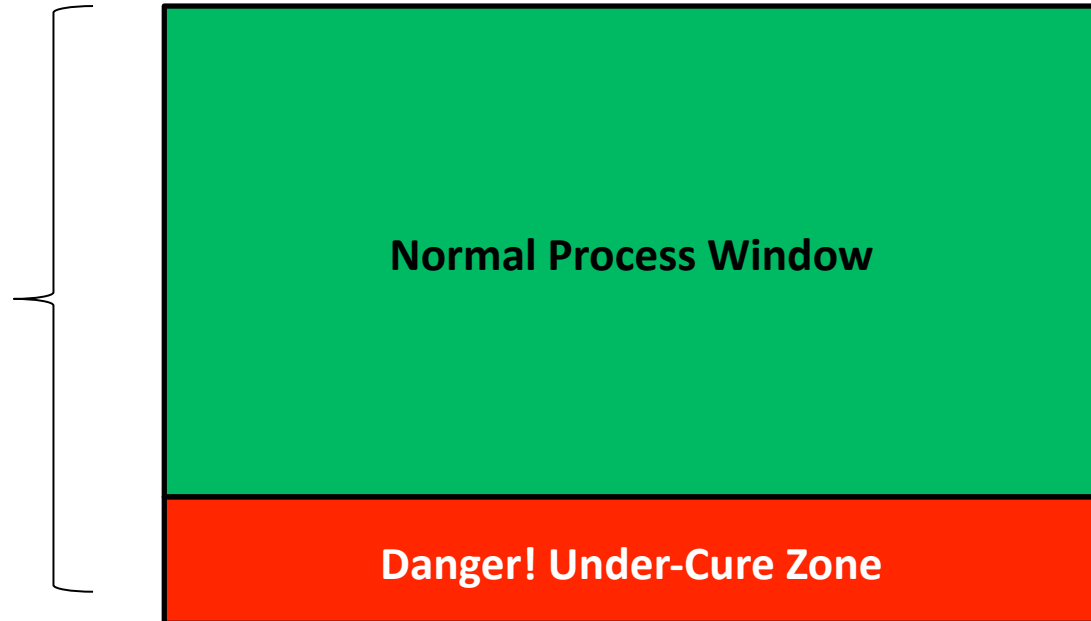


# Typical UV Process Window

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## Process Window

Zone which allows you to produce good quality product.

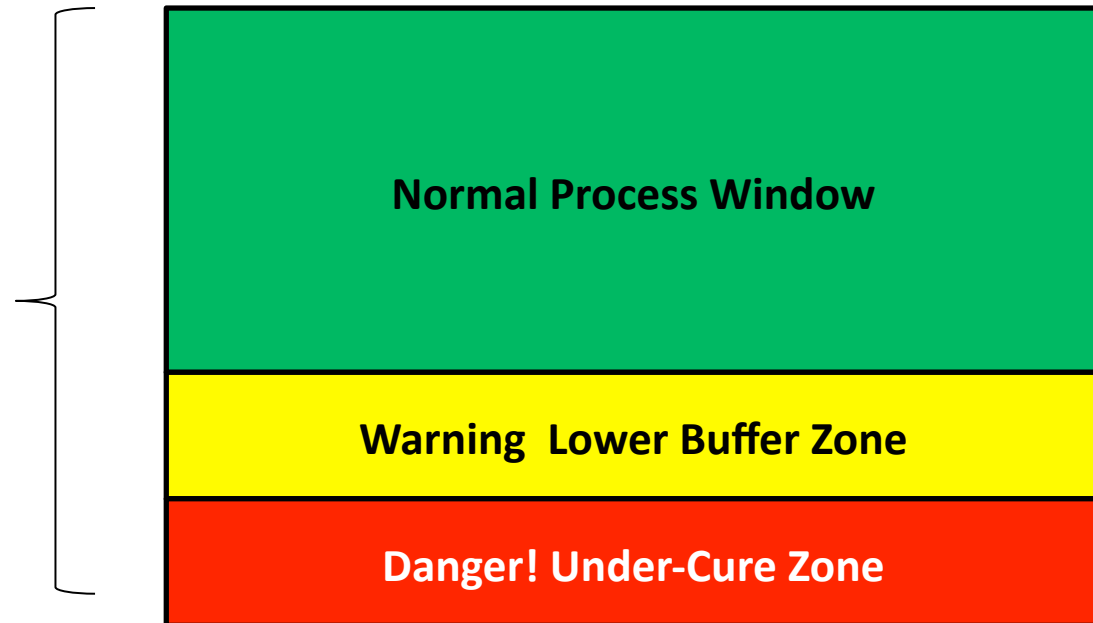




# Typical UV Process Window

## Process Window

Zone which allows you to produce good quality product.

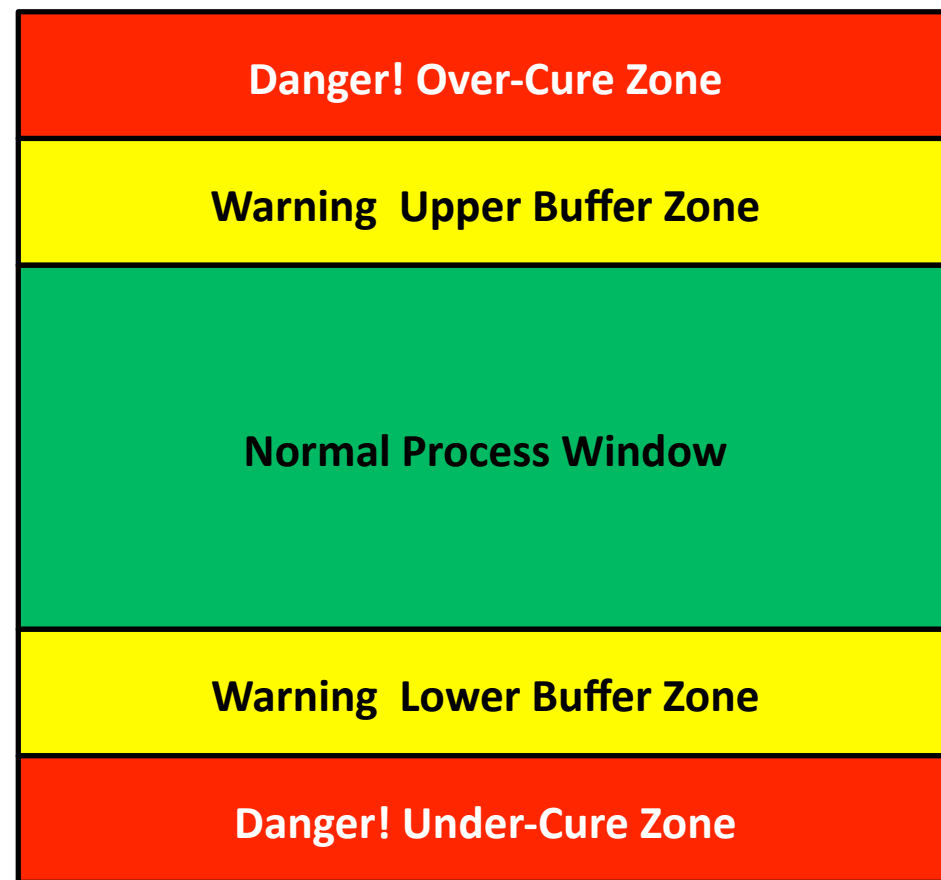




# UV PSA Process Window

## Process Window

Zone which allows you to produce good quality product.





# Many adhesive applicators are working blind.

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**“Anything that you can measure, you have a better chance of controlling. Things that you do not measure become the cause of mysterious problems”**

**- Larry Goldberg.  
Beta Industries**





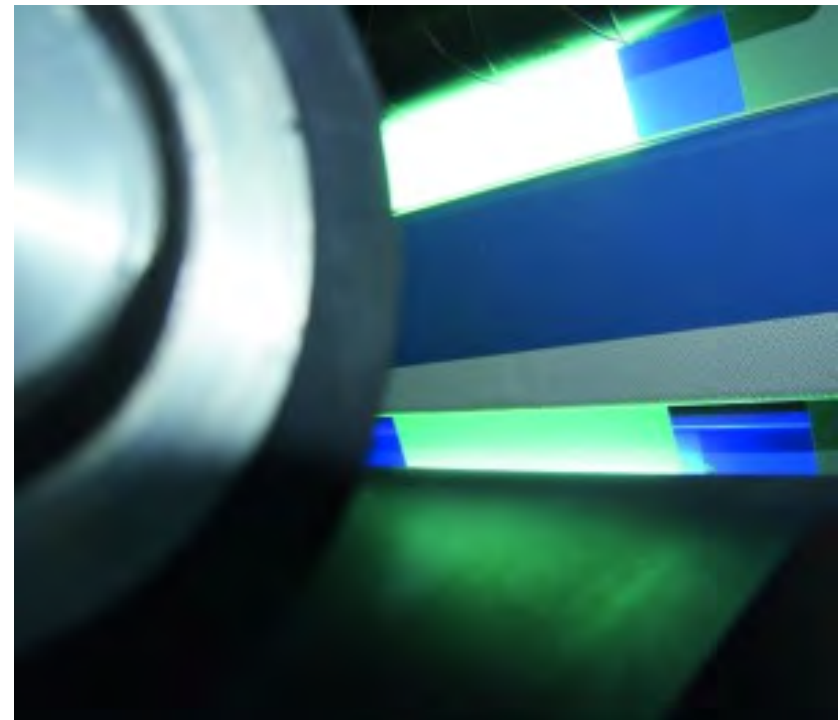
# UV PSA ISO of UV Photons

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## What could possibly go wrong?

UV adhesive properties rely not only on an adhesive's formulation, but on how the material is cured.

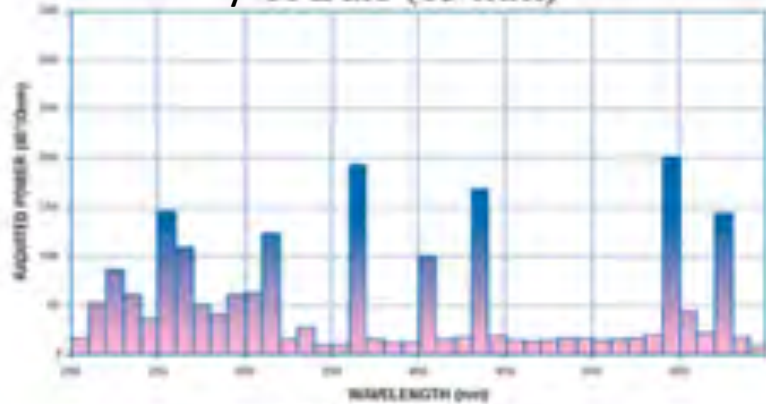
This includes the UV lamps wavelength, intensity (irradiance) and time of UV exposure (dose or energy density) and changes in these parameters.



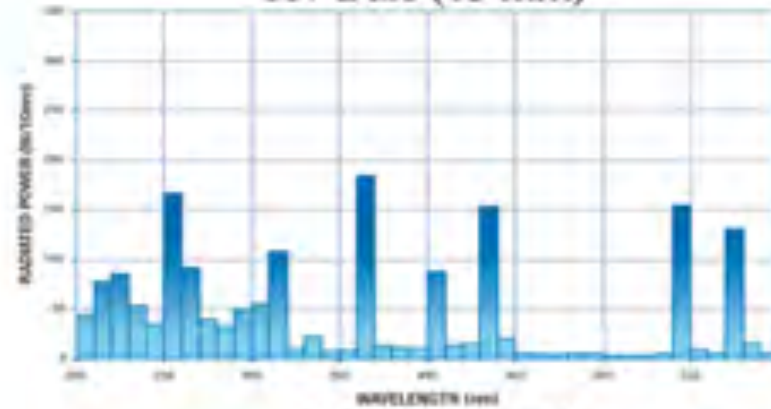


# Variable: UV Wavelength

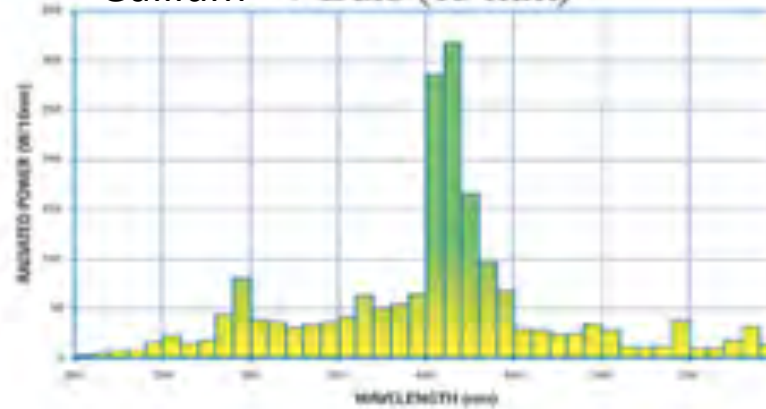
Mercury H Bulb (13 mm)



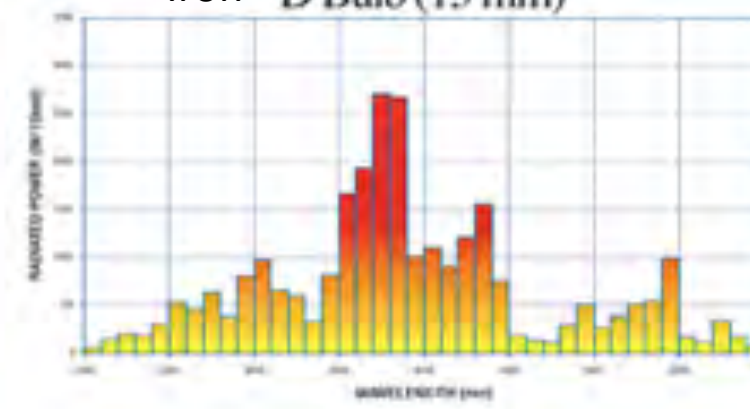
H+ Bulb (13 mm)



Gallium V Bulb (13 mm)



Iron D Bulb (13 mm)



Courtesy Heraeus Fusion UV





# Variable: UV Lamp Irradiance

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Irradiance, or how “bright” a UV source is varies with the design of the lamp, and distance from the lamp, power supply, bulb diameter.

Lamp irradiance is measured in Watts/cm<sup>2</sup>

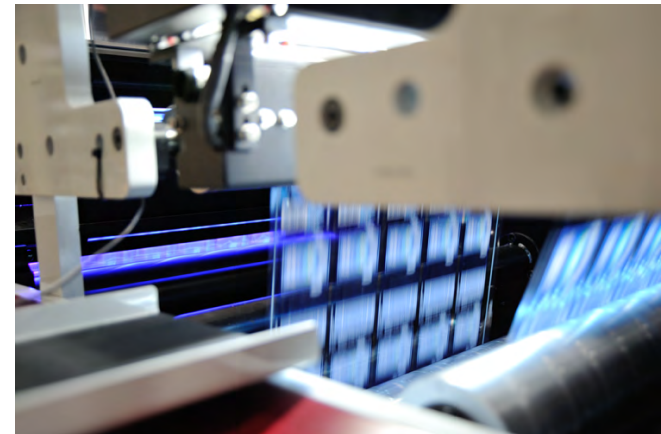




# Variable: UV Energy Density

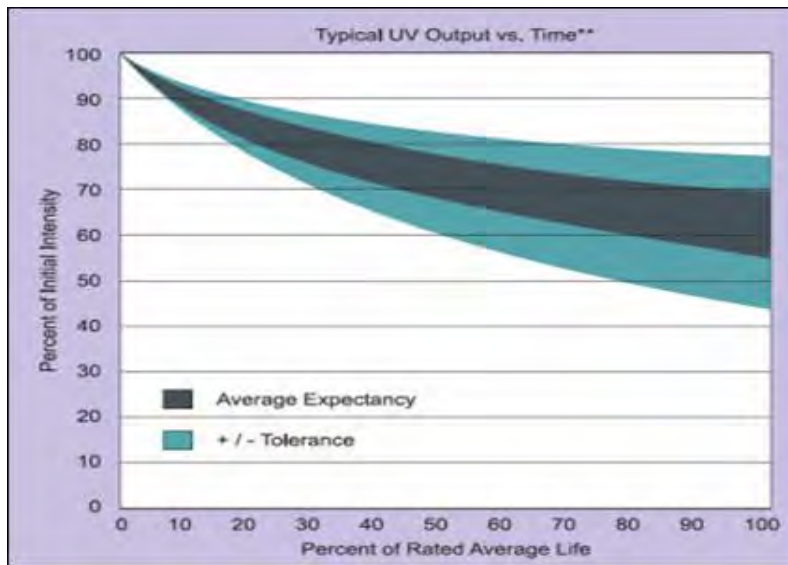
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- Since ***energy density = irradiance x time***, anything that affects either of these factors changes the energy density:
  - Line speed
  - Age of the lamp
  - Lamp output settings
  - Distance from the lamp to the PSA
  - The condition of lamp reflectors
  - Darkening of lamp electrodes





# Natural aging



**UV lamps age...**

**and so do coatings.**







# Lamp Symptoms- Aging



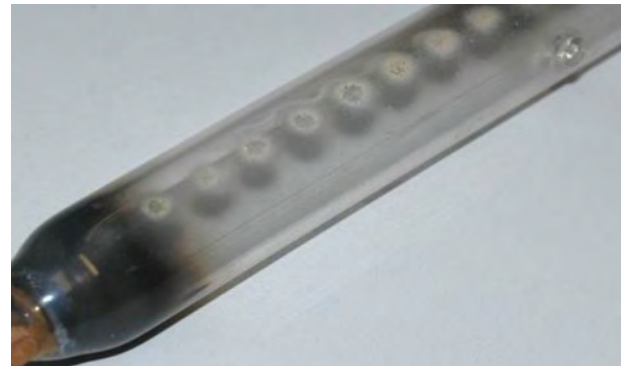
Devitrification / Clouding



Mirroring



Blackening / Erosion



Contaminated Airflow





# Lamp Uniformity

55" (140 cm) bulb



Irradiance mW/cm <sup>2</sup>		Data collected 3/24/16		
Band	Left	Center	Right	Highest Delta
UVA	797	983	635	35.4%
UVB	713	888	573	35.5%
UVC	200	257	167	35.0%
UVV	612	757	492	35.0%
Energy Density mJ/cm <sup>2</sup>				
UVA	243	282	234	17.0%
UVB	206	239	195	18.4%
UVC	58	68	55	19.1%
UVV	231	264	222	15.9%



# Instrument Cleanliness

Irradiance mW/cm <sup>2</sup>			
Band	Before	After	Difference
UVA	1223	983	-19.6%
UVB	1066	888	-16.7%
UVC	277	257	-7.2%
UVV	889	757	-14.9%



Data collected 3/24/16

Before: Data collected with contaminated optics

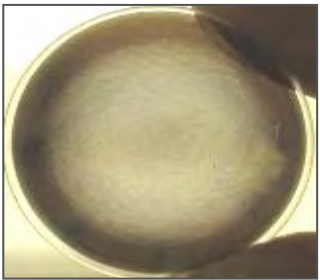
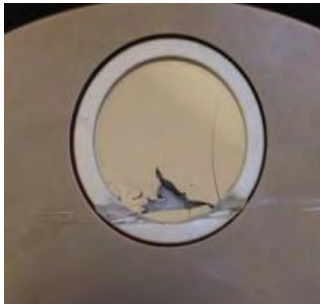
After: Data collected after cleaning

Energy Density mJ/cm <sup>2</sup>			
Band	Before	After	Difference
UVA	349	282	-19.2%
UVB	284	239	-15.9%
UVC	75	68	-9.33%
UVV	309	264	-14.6%





# The Blame Game





# Factors that can affect UV cure performance

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- Adhesive film thickness
- Settling/ inadequate mixing
- Shelf life
- Substrate reflectivity
- Inadequate surface preparation





# Adhesive film thickness and UV cure

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For medium to high tack, suggested coating weights are 0.5 mils and up. Higher coating weights require more “curing power”.

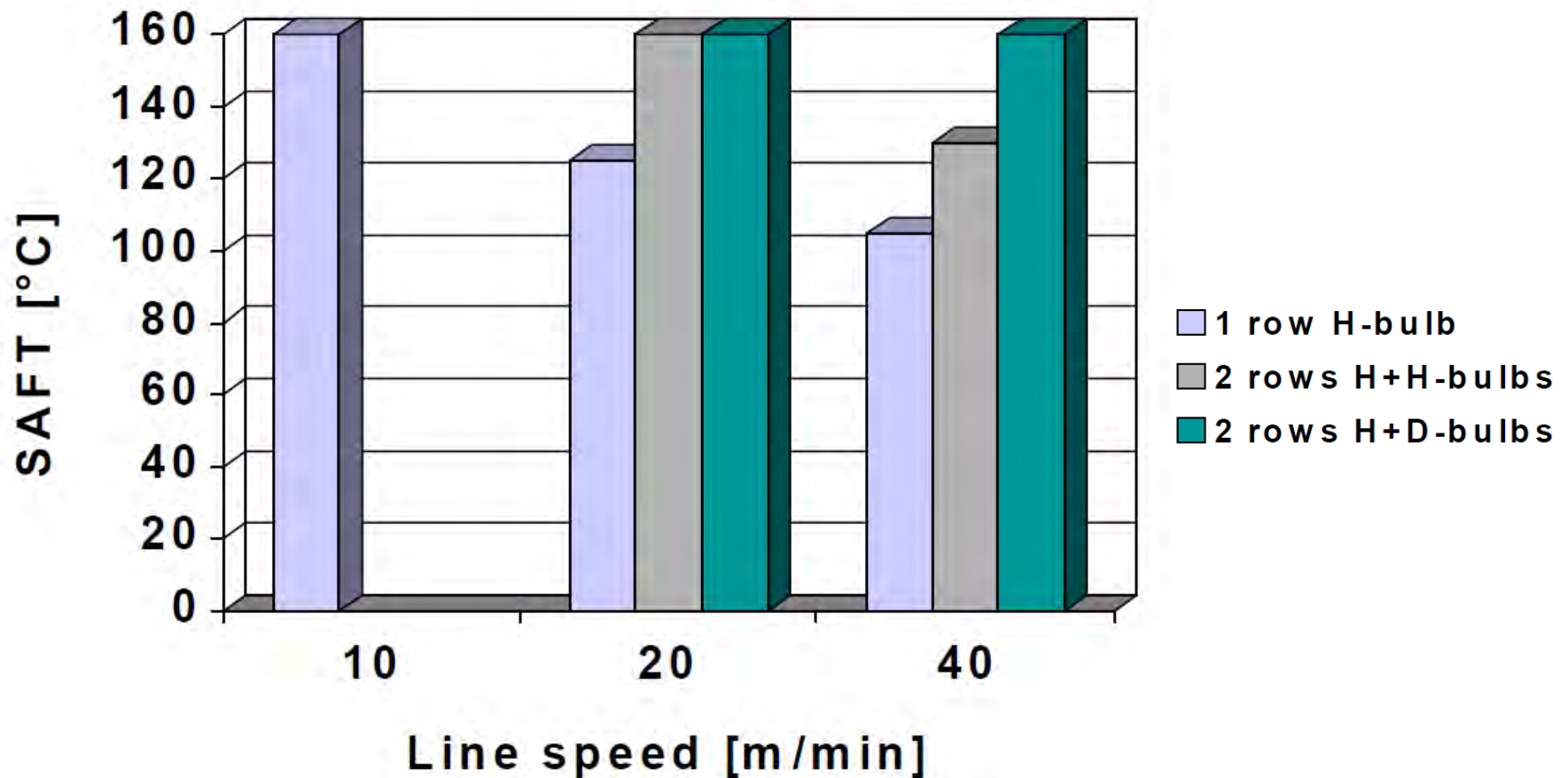
This may be achieved by adding more lamps, increasing the wattage of the lamps, changing to a deeper penetrating bulb, or by slowing down press speeds. For proper cure and optimum adhesive results, one or more of these methods may be required.







# Effect of Energy Density on PSA Adhesives



Source: Burger, Skinner, Field & Draper,  
*Experiences with UV Curable PSAs on a Production Facility*







# Adhesive thickness

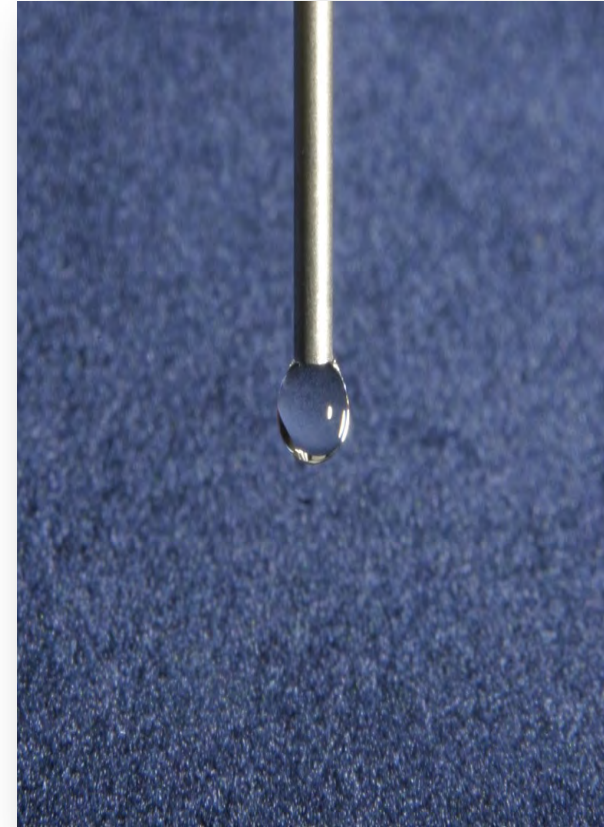
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## **Conventional PSAs:**

Wet thickness and dry thickness can vary a good deal. The difference depends primarily on solids content and coating method.

## **UV Curable PSAs:**

Wet thickness, and cured film thickness are theoretically nearly the same, but can be influenced by flow before cure, depending on viscosity.





# Printable PSAs

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A printable PSA is a high viscosity liquid. You need some flow to wet out the material. Too much cure, will be too crystalline for the adhesive to flow and properly wet-out/grip the substrate.





# Printable PSAs

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A printable PSA is a high viscosity liquid. Flow is necessary to wet out the material.

Over-cure can cause the material to become too crystalline for the adhesive to flow and properly wet-out/grip the substrate.





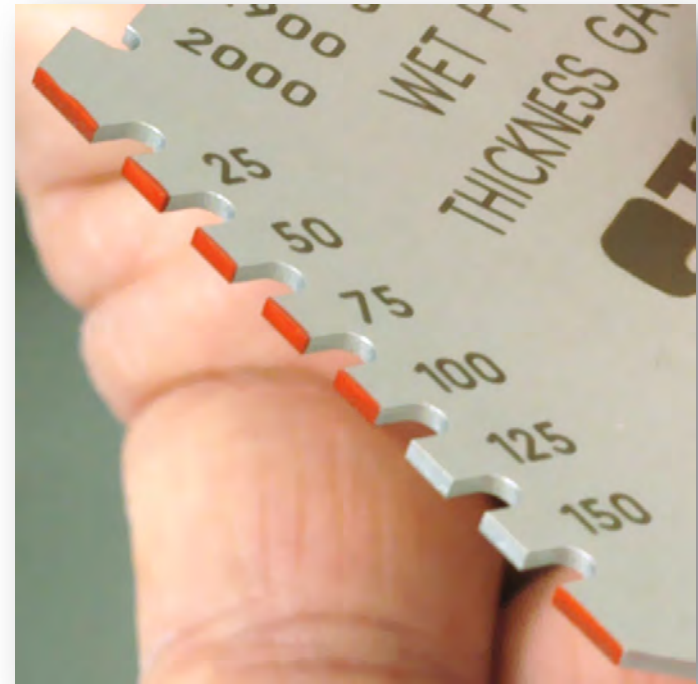
# Adhesive film thickness

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Printable UV cure PSA formulas are generally formulated with a relatively wide exposure latitude.

KIWO suggests testing with 92 thread/in. mesh with 92 micron thread diameter. This yields around 2 mil cured thickness providing a balance of achievable strength versus cost.

Always verify that the UV exposure recommendation will cure the entire range of anticipated film thickness.





# Proper Mixing

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- Frequently, UV PSAs will not require stirring, as they do not settle/separate to the same extent as water based /conventional systems.
- As with inks, UV cure PSAs should be stirred before use - especially if separation is evident - taking care not to introduce air bubbles in the process.
- Hand/machine stir: A dispersion blade has the advantage that you can let it run with a slow speed/lower setting, without introducing much air.
- In the container, UV PSAs commonly appear slightly translucent or hazy, sometimes with a slight almond cast.
- Though not always visible, settling/separation does occur. You may see a filmy white appearance or swirl in the adhesive - this is defoamer separation.





# Proper adhesive storage

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- It's generally safe to store UV curable PSAs in the same conditions as water based/ solvent based PSAs.
- Do not store/transport at higher temperature than 40C / 104F.
- Do not store in sunlight / UV light.
- You do not have to protect from freezing; though, after exposure, the product should be brought to room temperature and properly stirred.





# Shelf life

## Shelf life

Depends on the product, some minimum 6 mo., some max. 1 year. As these age, the sensitivity to UV curing erodes. With some formulations gelling (spelling) occurs.

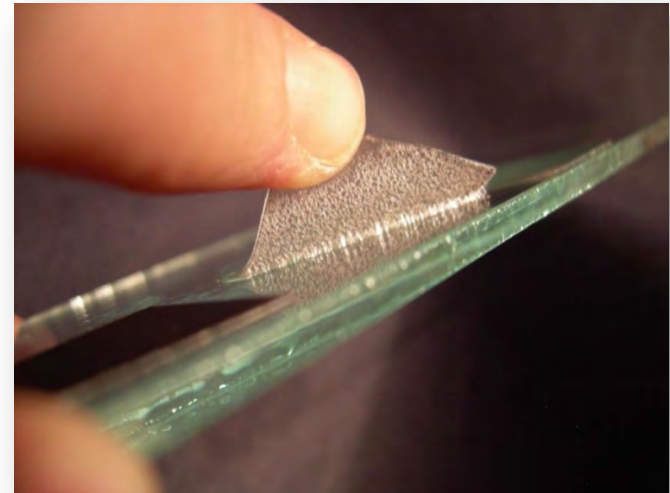




# Substrate-adhesive affinity

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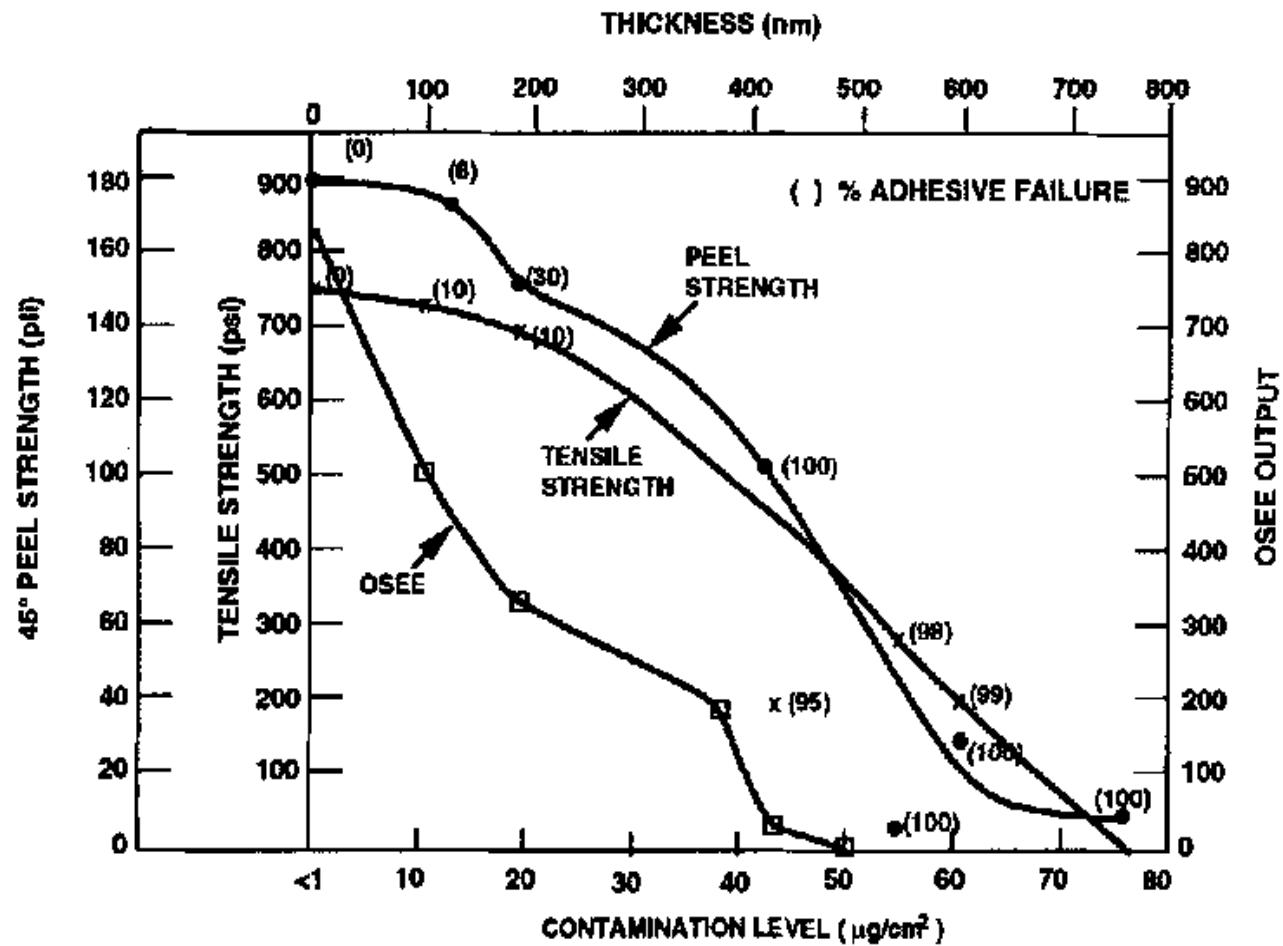
Affinity of the adhesive formulation to substrate...paper, metal, or plastic will determine the bond strength. The lower the substrate's surface energy, the more difficult it is for the adhesive to wet-out and strongly grip the surface.



Surface treatment is good practice to achieve higher bond strength. Polyolefins (e.g., PP and PE) require treatment. The low temperature resistance of these plastics requires additional consideration, because the thinner grades will distort under the higher dosage required to cure 1-2 mil films.



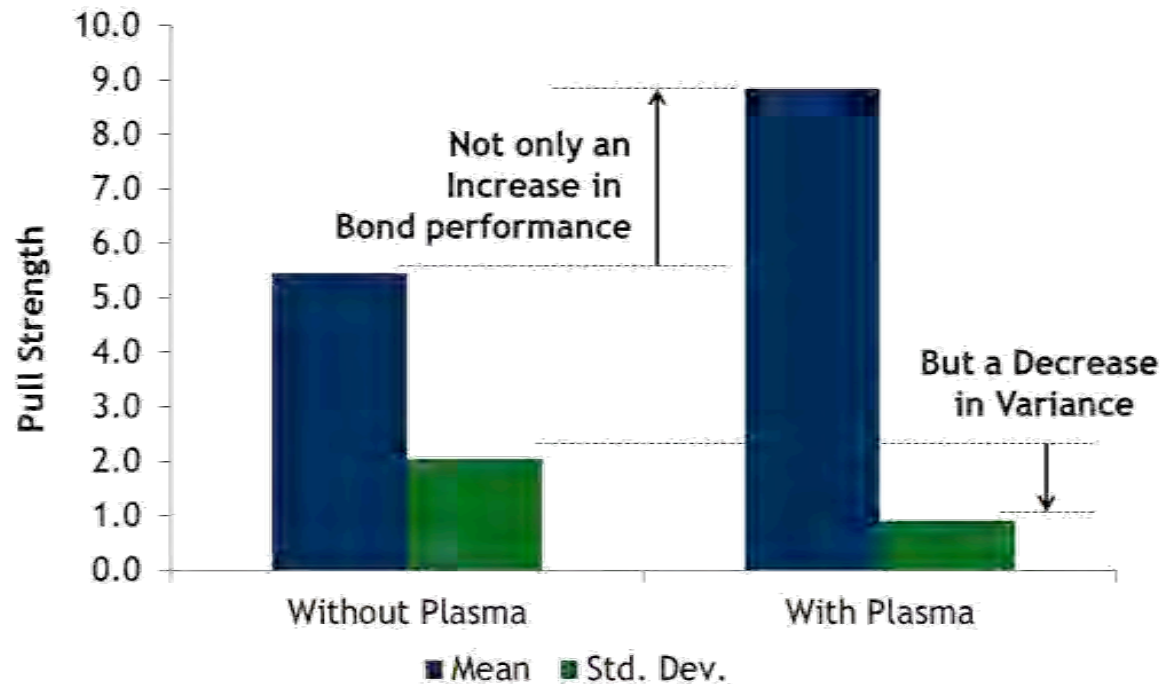
# The Importance of a clean surface





# Affect of surface energy on bond strength

Pretreatment may aid in the bonding performance of an adhesive. Substrates can be treated with corona, flame or chemical pretreatment.



(Source: Kegel & Schmid 1999)



# Substrate color & reflectivity

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Darker surfaces absorb more light energy and a darker surface heats up more than a white one. ***In practice***, most variation is offset by the exposure window, so that little adjustment is usually needed.

Shiny metals, for example, are like white reflect the light which aids in exposure. Therefore reflective colors can be expected to be on the shorter end of exposure scale.



# Summary

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- UV Cure PSAs are particularly sensitive to UV exposure levels
- Establish a process window. Consider the upper and lower bounds.
- Many factors can contribute to failure, both natural and self-inflicted. Be vigilant.
- Measure your process to ensure you are operating within the process window



# Questions ??

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## Contact Information

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