SIEGWERK

MECHANICS OF INK ADHESION

APR Narrow Web Flexible Packaging Summit

John Kilbo
OFC Regional Technical Manager

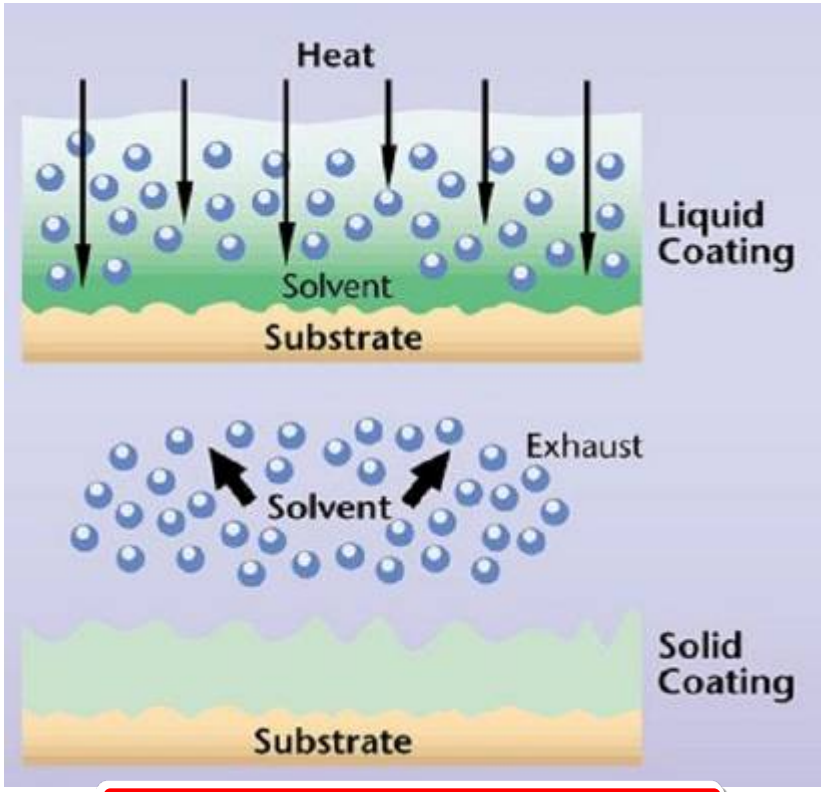
Nov. 9th, 2017

AGENDA – SOME TOPICS

1. Adhesion Mechanics – What causes adhesion
2. Inline Treatment – How and Why
3. UV / UV LED Radiation Curable Aspects
4. What the Printer Can Control
5. How to Measure, QC Procedures

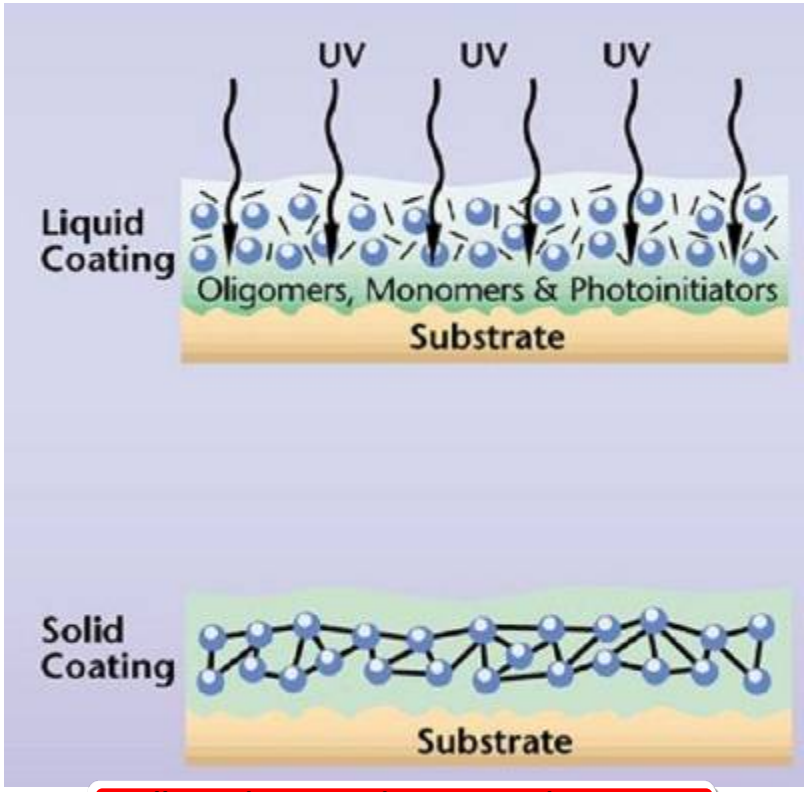
UV vs. CONVENTIONAL CURING

Conventional curing



- Substantial evaporation with wet coating

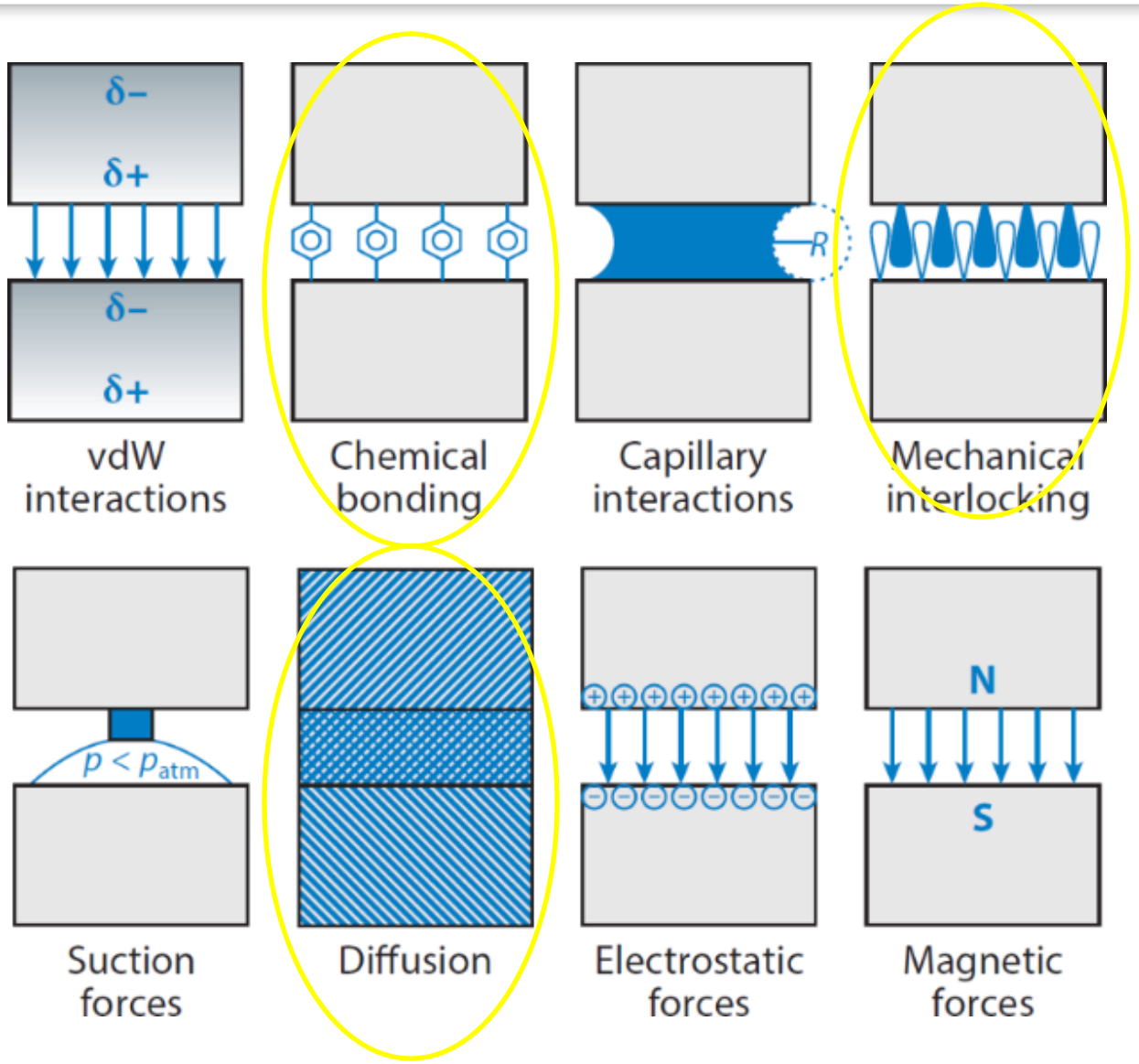
UV curing



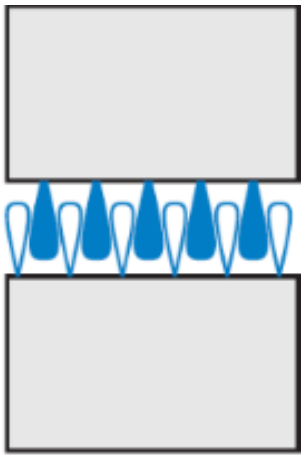
- "Nothing is leaving the system" – no evaporation with UV ink

SIEGWERK

WHAT CAUSES INK ADHESION



SIEGWERK



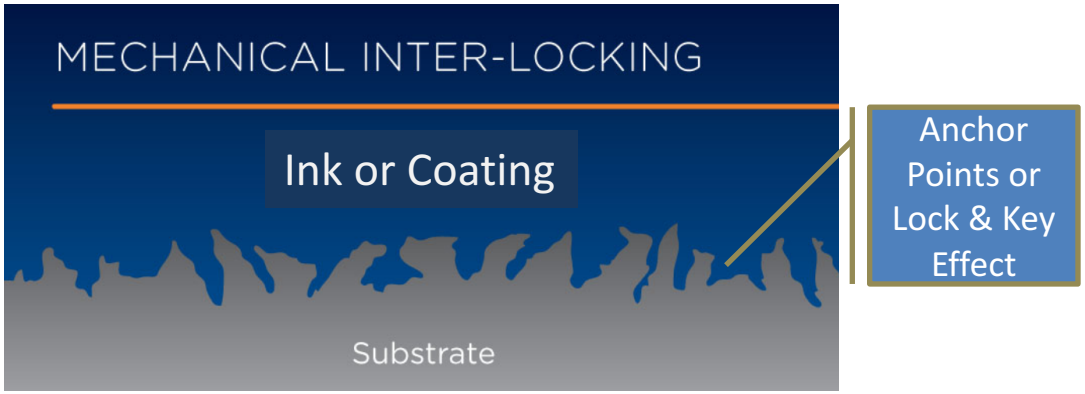
Mechanical interlocking

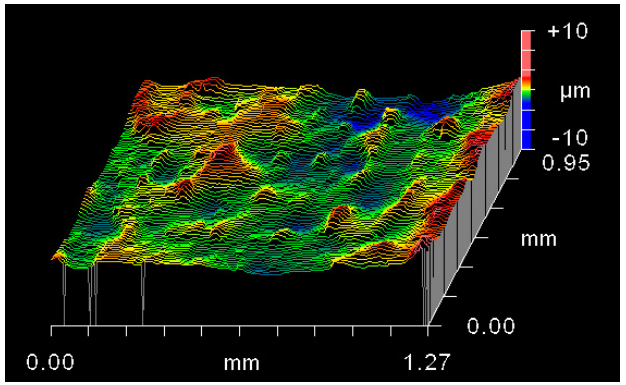
Mechanical Adhesion

Definition:
Ink fill the voids or pores of the surfaces and hold surfaces together by interlocking which in turn build high separation forces. Surface area is increased dramatically.

How to Enhance:

- Full Reaction at the Base Layer (hardened base layer fully anchored in)
- Post Treatment (corona, flame) can raise irregularities.
- Ensure Proper Surface Energy (Dyne Level) or Additives to Speed Dynamic Wetting Conditions.



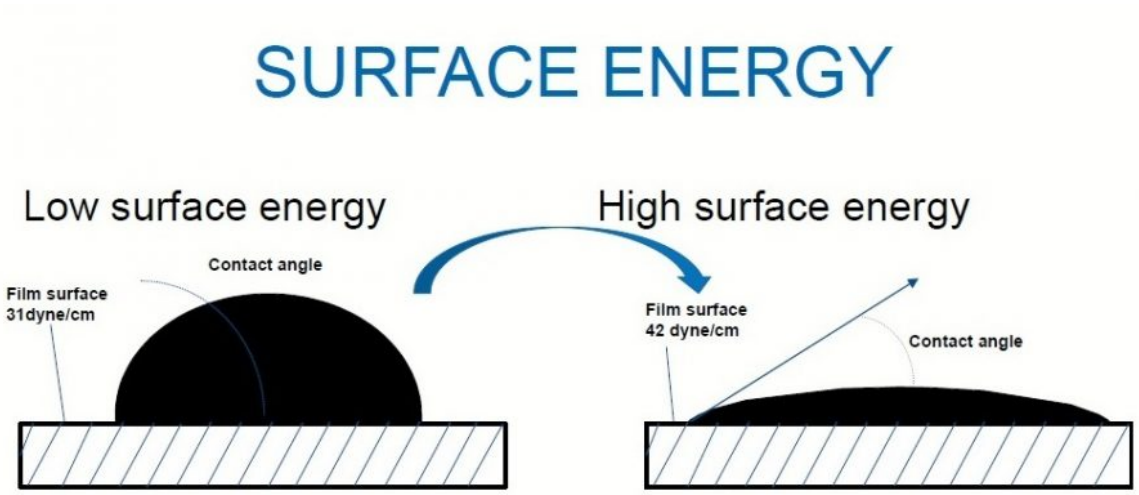


PROPER SURFACE ENERGY (dyne level)

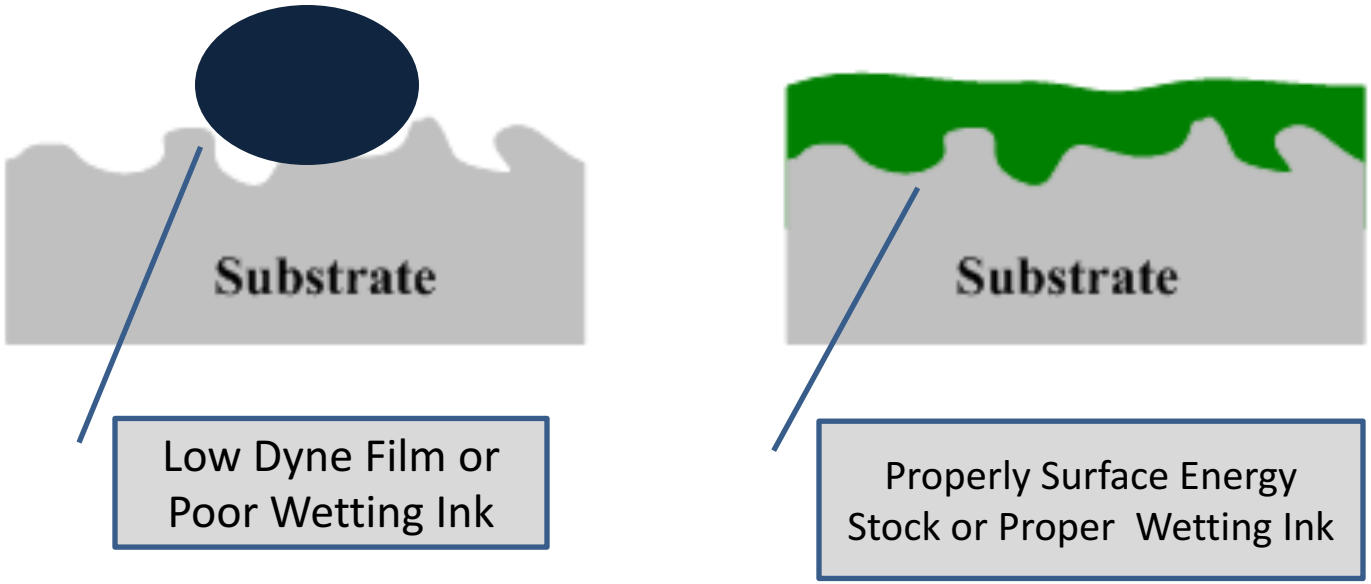
Surface Energy Definition:
The **surface energy** is defined as the sum of all intermolecular forces that are on the surface of a material, the degree of attraction or repulsion force of a material surface exerts on another material.

What Proper Surface Energy Provides:

- Smooth Even Wet Out for Clean Aesthetics
- Maximized Contact (Mechanical Adhesion, Diffusive Adhesion even Chemical Adhesion are at max potential)

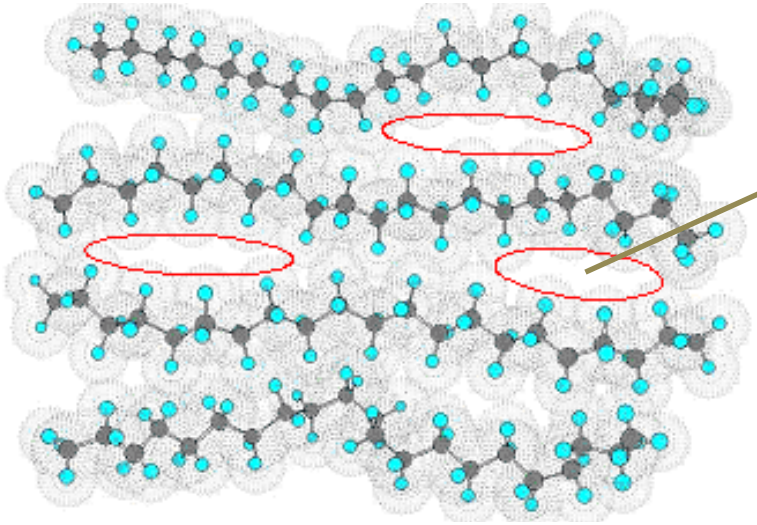


MECHANICAL ADHESION – ACCELERATOR OR DECELERATOR

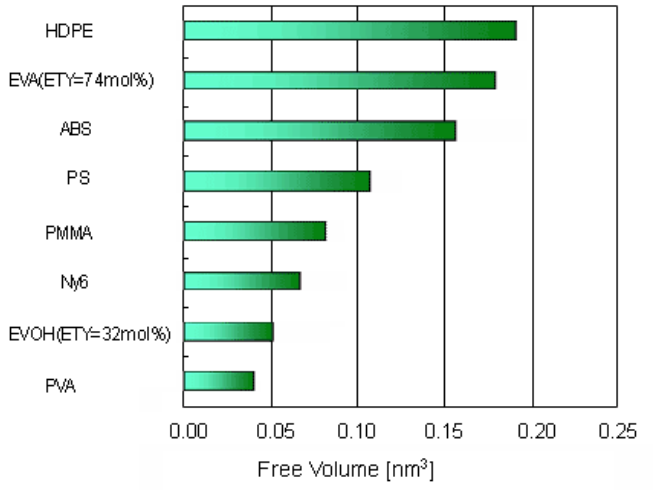


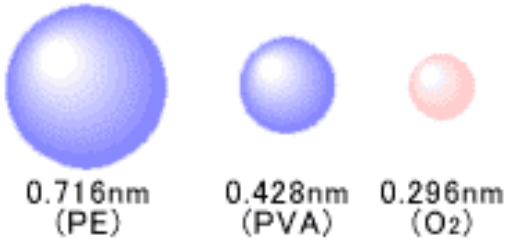
SIEGWERK

HIDDEN MECHANICAL ADHESION – PLASTIC FREE VOLUME



FREE VOLUME IN PLASTIC
pores – gases and other small molecules can move freely



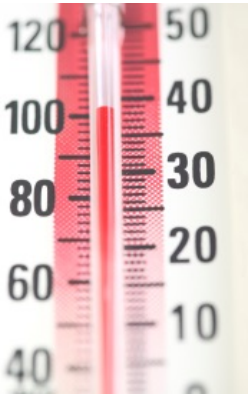


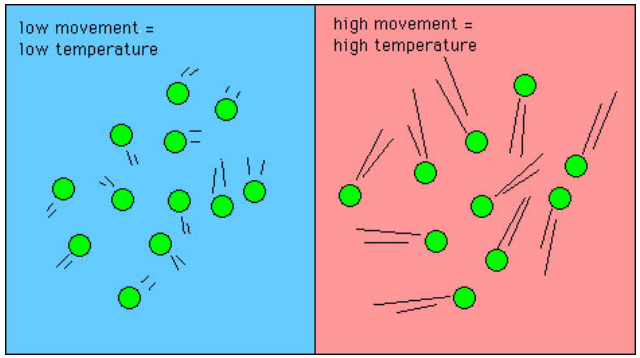
Free volume of PE and PVA, and size of the oxygen molecules. The diameters are the figures shown here. The size of the oxygen molecules are measured from the viscosity.

SIEGWERK

COLLISION FREQUENCY – BENEFITS OF HEAT IN UV CURING

GENERAL RULE OF THUMB FOR CHEMCIAL REACTIONS IS EVERY 10C THE TEMPERATURE IS INCREASED THE REACTION SPEEDS DOUBLE

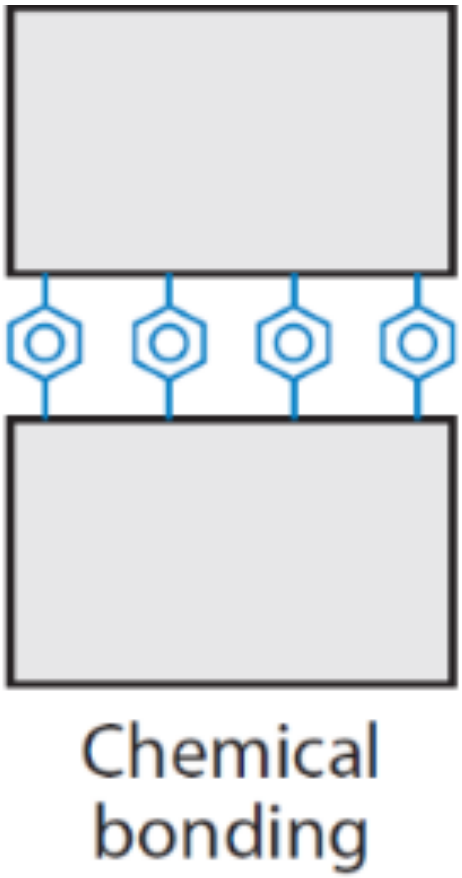




SHRINK FILM
Coin Scratch 85F Web Temp

SHRINK FILM
Coin Scratch 95F Web Temp

SIEGWERK

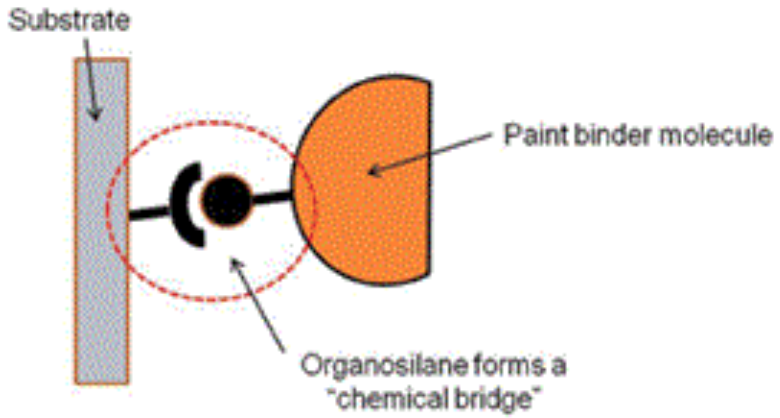


Chemical Adhesion

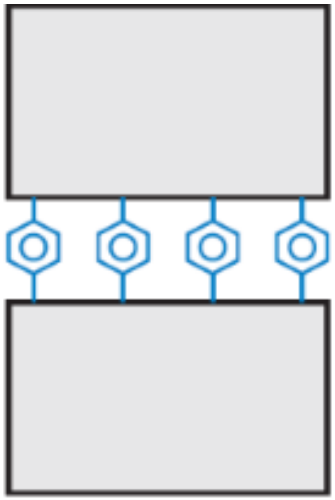
Definition:
Strongest adhesion force. Two chemicals reaction to form a continuous molecule.

How to Enhance:

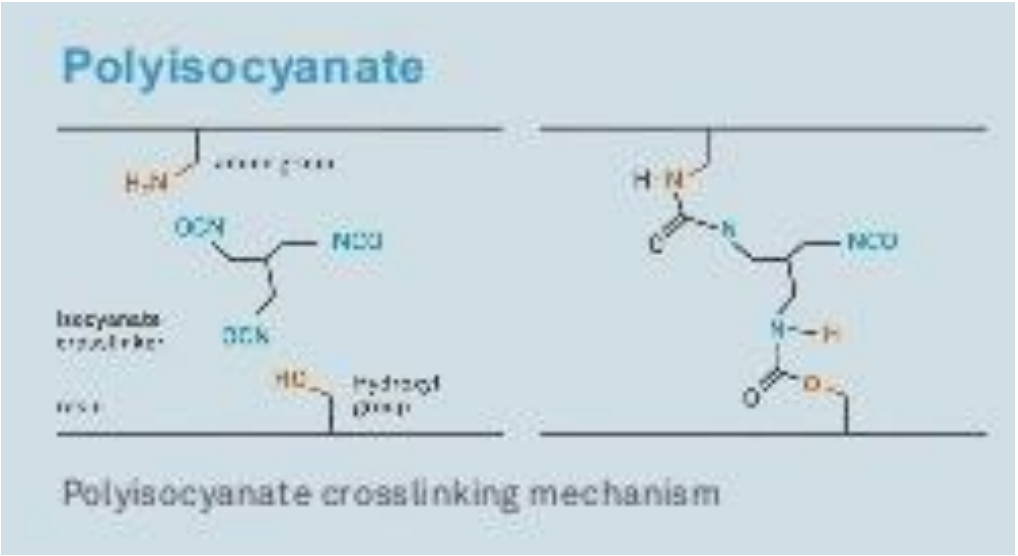
- Secondary Catalysts (ex. Isocyanates, Aziridine)
- Corona Treatment can add possibilities
- Built in Chelation Adhesion Promoters

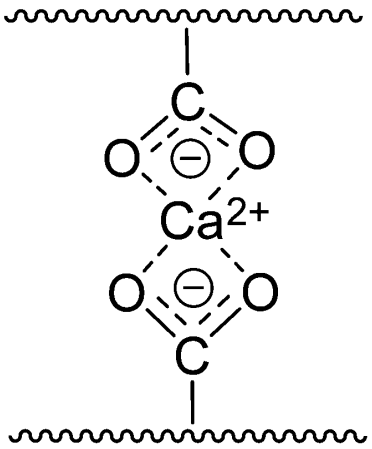


CHEMICAL ADHESION



Chemical bonding





SIEGWERK

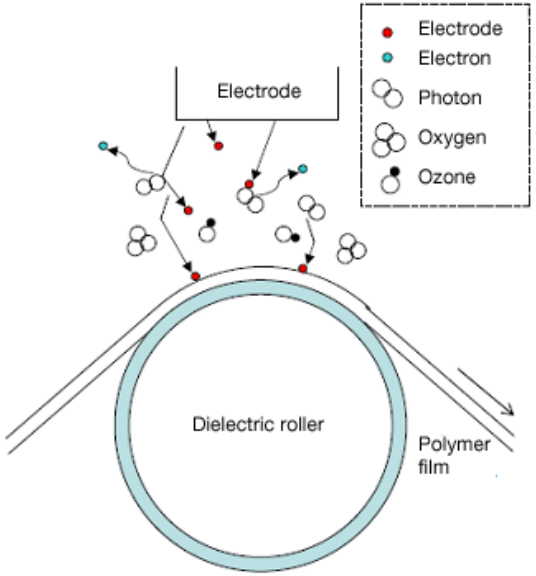
Corona Treatment

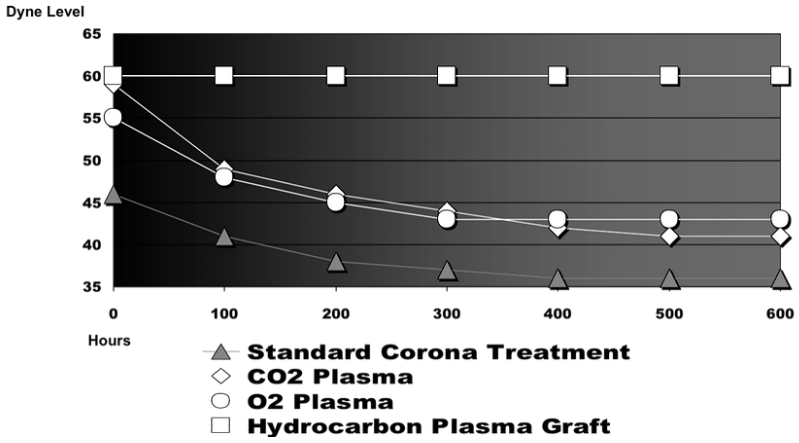
Definition:
Corona treatment is a high frequency discharge that increases the adhesion of a plastic surface.

During Corona treatment electrons are accelerated into the surface of the plastic causing the long chains to rupture, producing a multiplicity of open ends and free valences are formed. The ozone from the electrical discharge creates an oxygenation, which in turn forms new carbonyl groups with a higher surface energy.

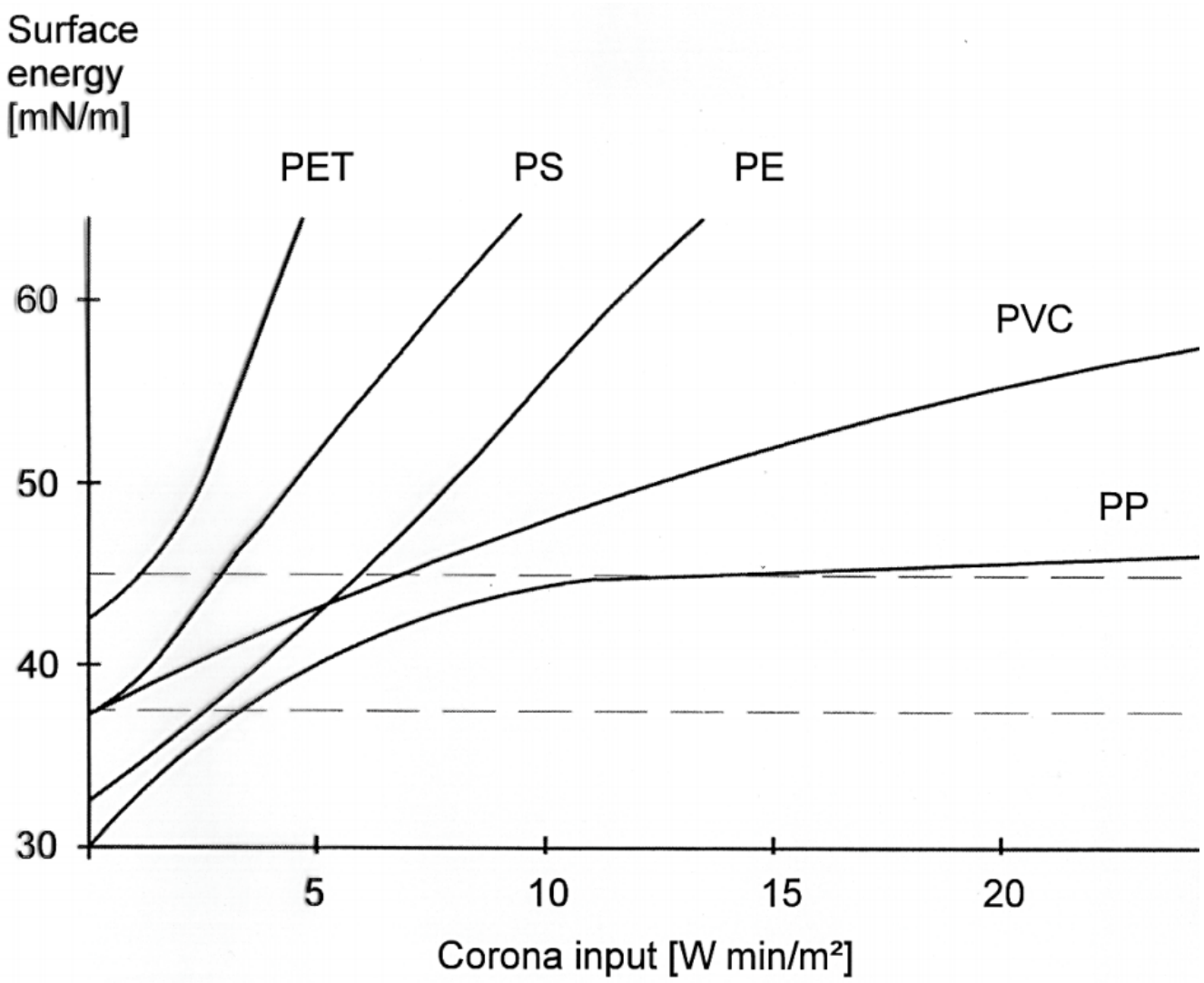
What Corona Treatment Provides:

- Improved Surface Energy – Corona installs a layer of oxygen onto the film which raises the surface energy causing inks/coatings/adhesives to wet better and receive full contact between film/ink..
- Oxygenated Layer – The installed functionality onto the films surface opens up possiblities for chemical adhesion that did not exist prior.
- Surface Irregularities – Micro surface Irregularies create additional mechanical adhesion thru higher surface contact.





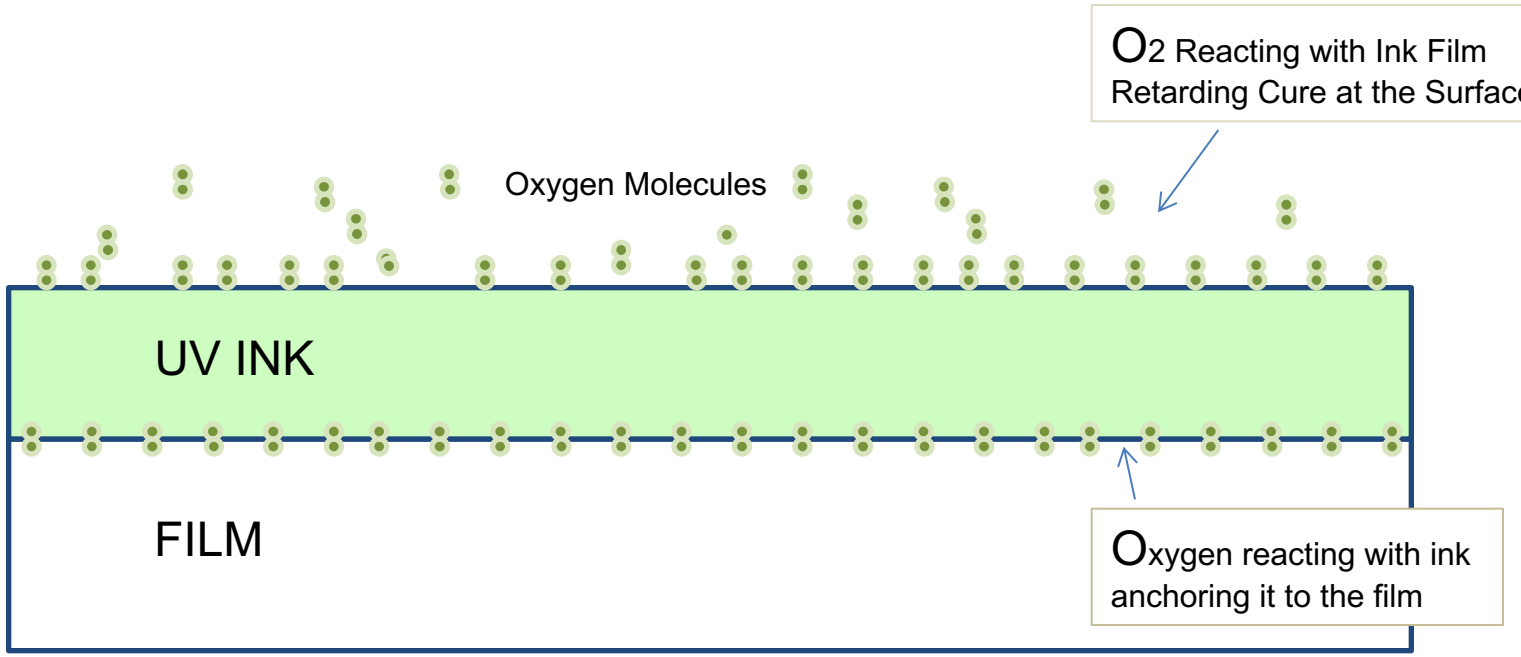
TREATABILITY of DIFFERENT FILMS

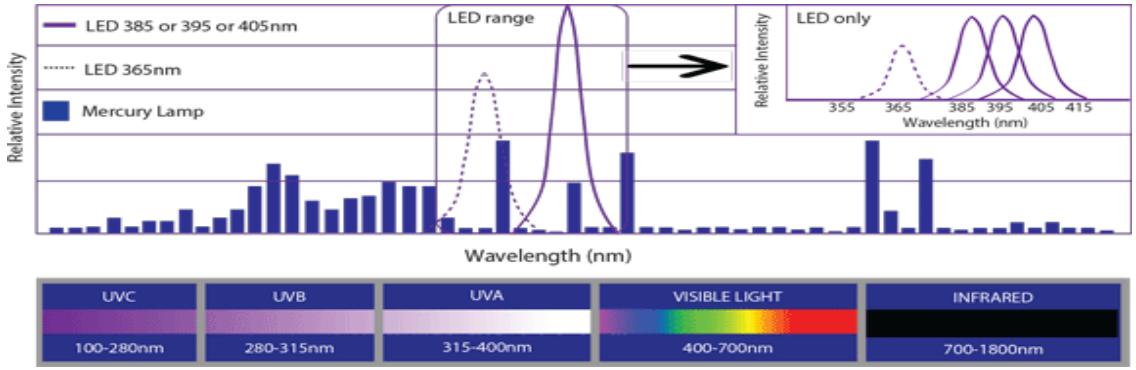


TREATABILITY of DIFFERENT FILMS

FILM TYPE	TOP COATING	SPEED (fpm)	CURE POWER LEVEL	TREATMENT LEVEL	DYNE LEVEL	INITIAL CROSSHATCH ADHESION (TESA SILICONE TAPE)
2M CL BOPP/S6972	Yes	250	40	0	38	50%
2M CL BOPP/S6972	Yes	250	100	0	38	80%
2M CL BOPP/S6972	Yes	250	40	0.2 kw	40	100%
2M CL BOPP/S6972	Yes	250	60	0.2 kw	40	100%
2M CL BOPP/S6972	Yes	250	100	0.2 kw	40	100%

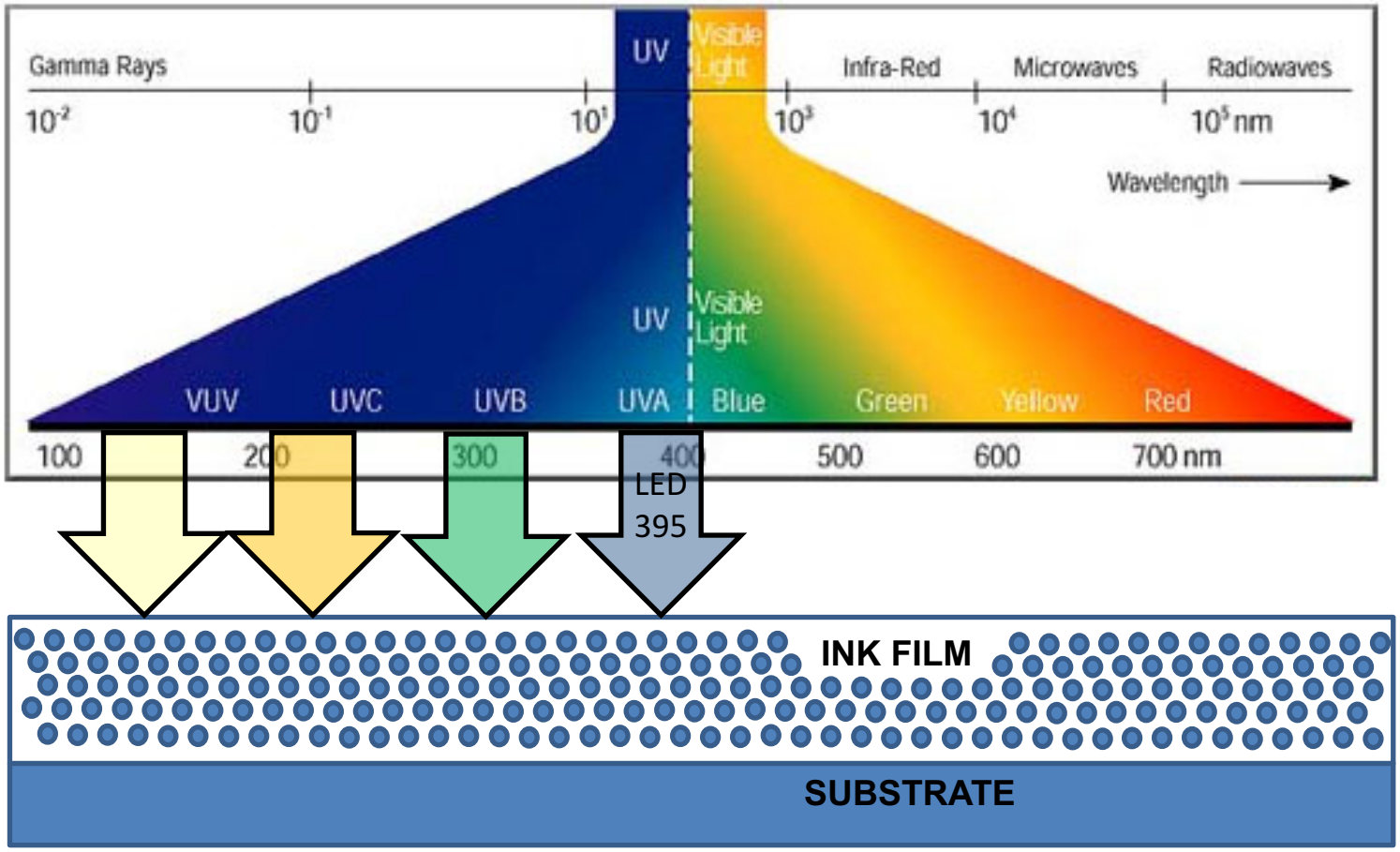
SURFACE CURE - OXYGEN INHIBITION





SIEGWERK

UV WAVELENGTH INK FILM PENETRATION



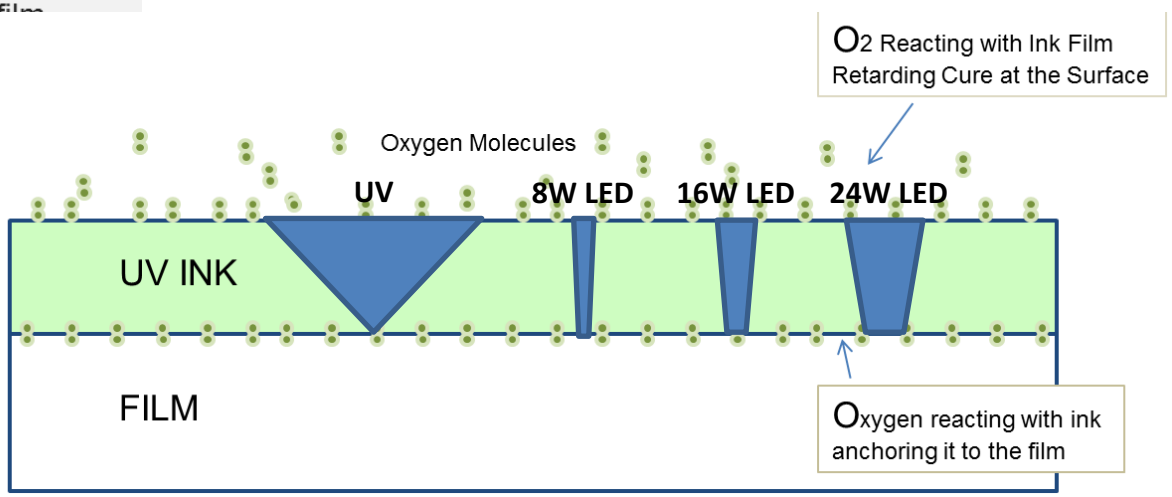
SIEGWERK

Corona Treatment – Synergy with UV LED

Corona Treatment = Press Speed

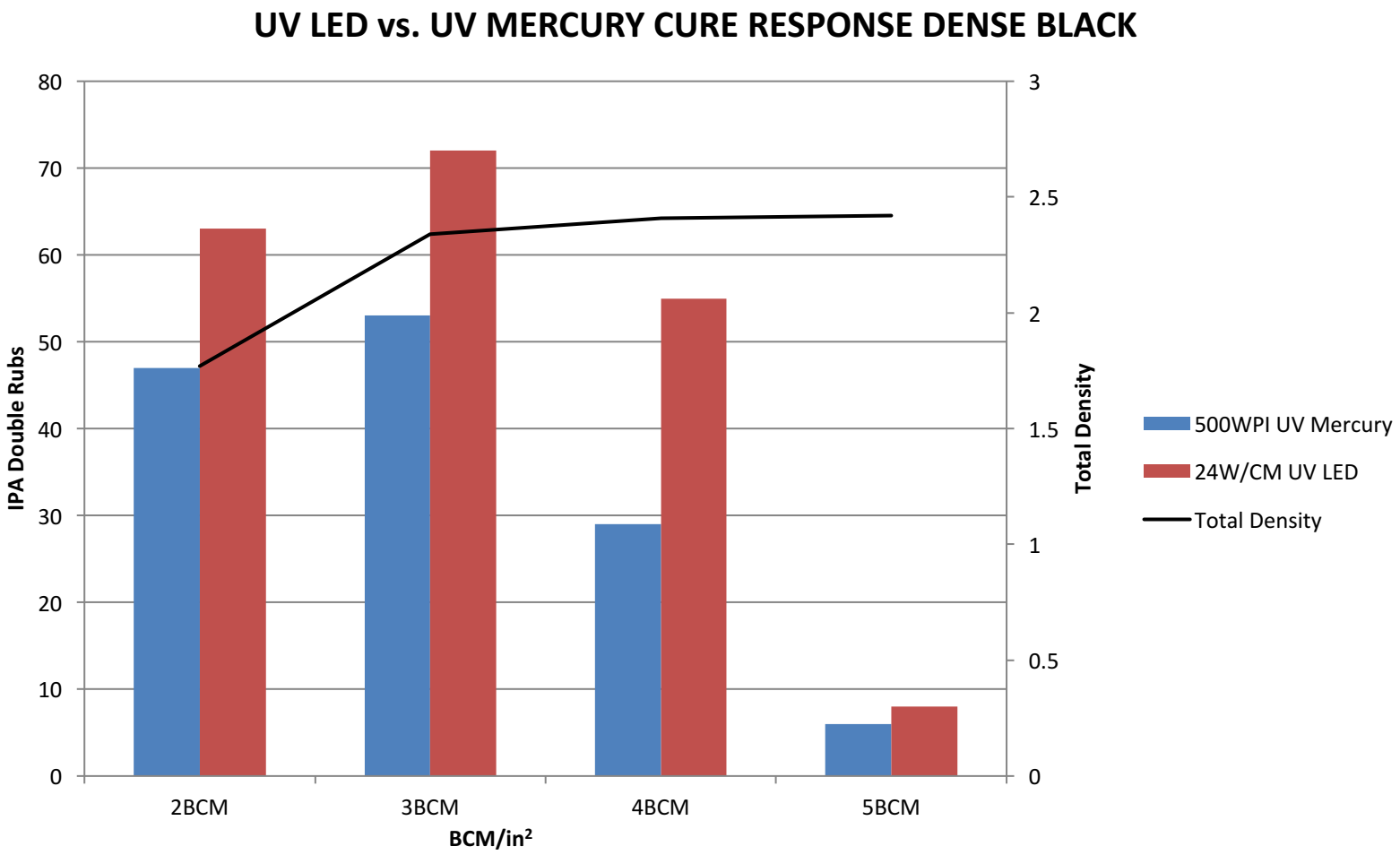
- Oxygen is electron rich highly reactive and will bind onto free radicals generated from splitting photoinitiators and growing polymer chains at the surface quenching the reaction.
- This same negative quenching at the surface can be used as an adhesion speed booster at the ink/film interface to chemically react the growing chair Adhesion at faster press speeds.

75% PETG Shrink Film with



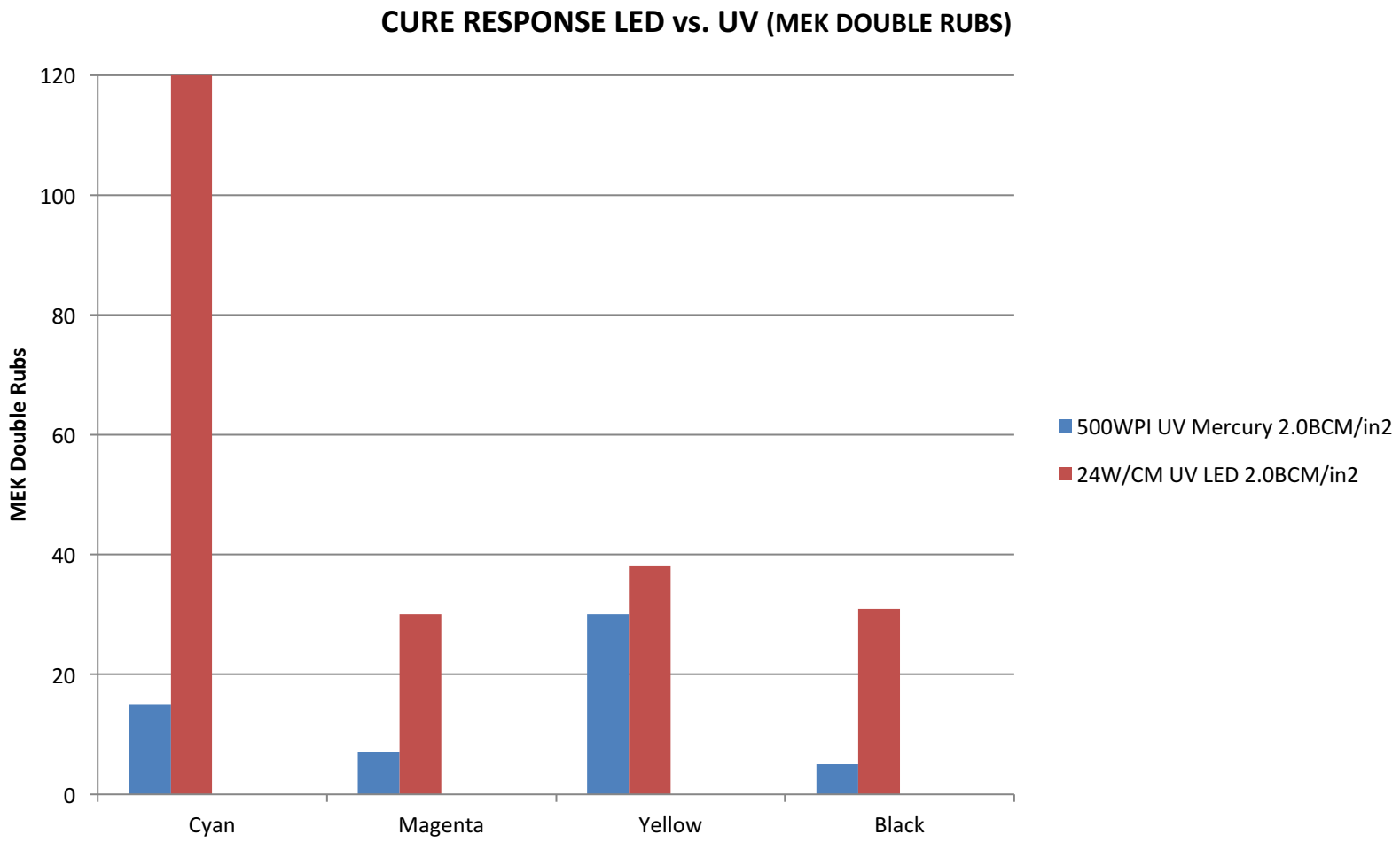
SIEGWERK

UV vs. UV LED (395nm) Cure Response – Dense Black



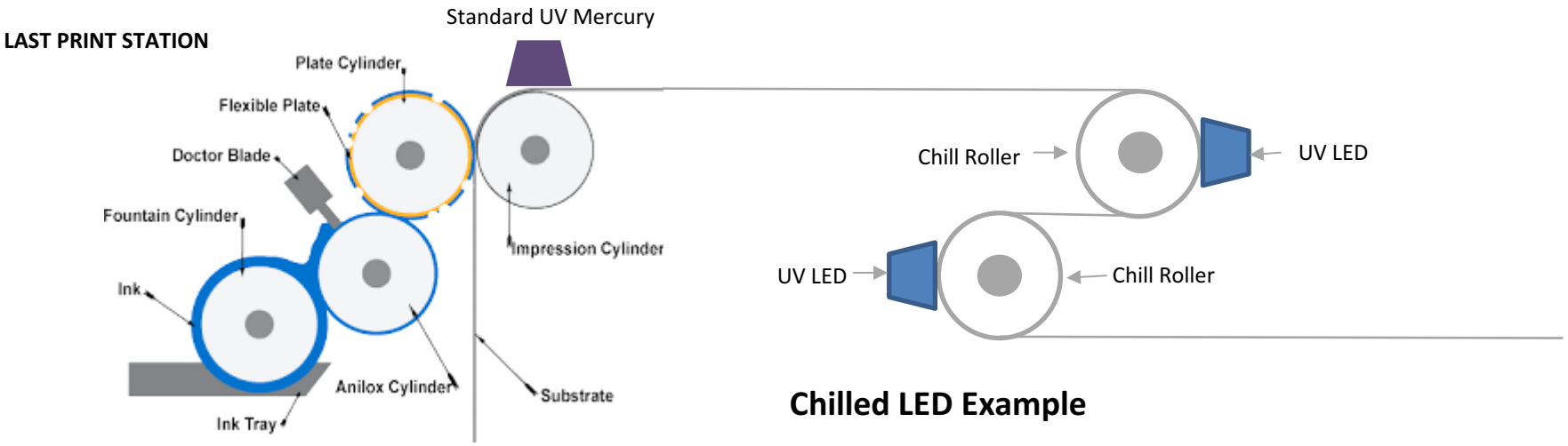
SIEGWERK

SICURA FLEX UV vs. UV LED (395nm)
Cure Response – CMYK

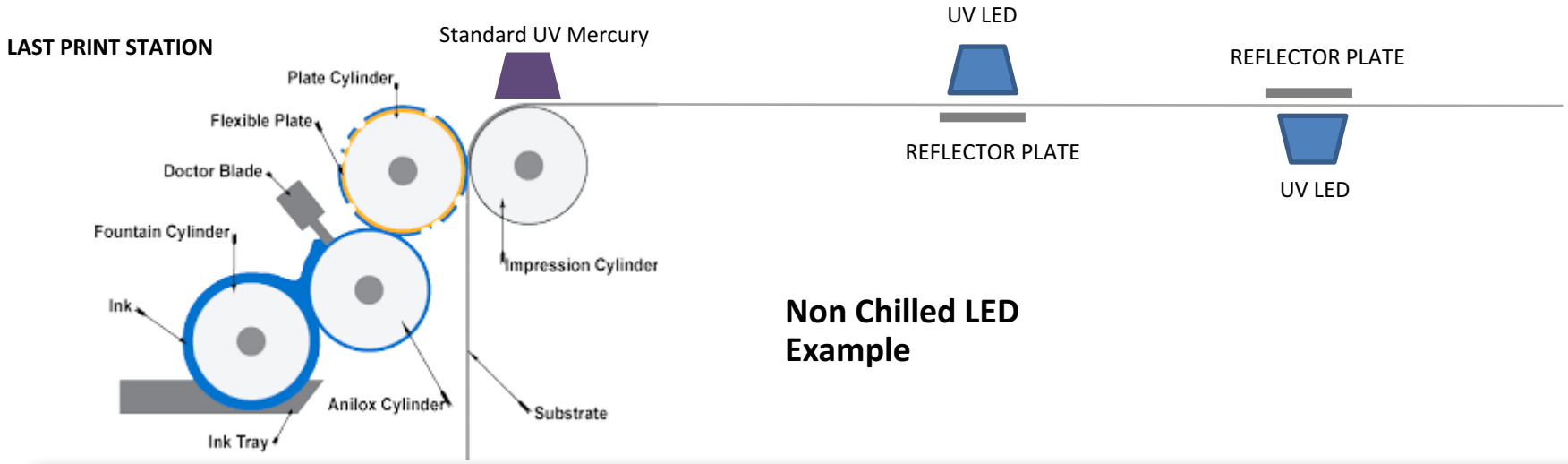


SIEGWERK

Low Cost LED Speed Enhancement Add on Concept

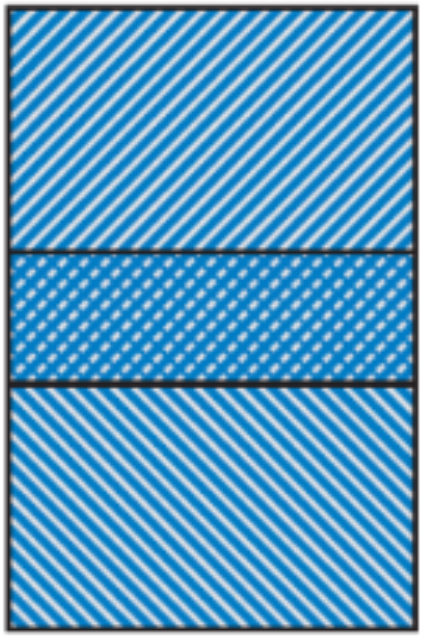


Chilled LED Example



Non Chilled LED Example

SIEGWERK



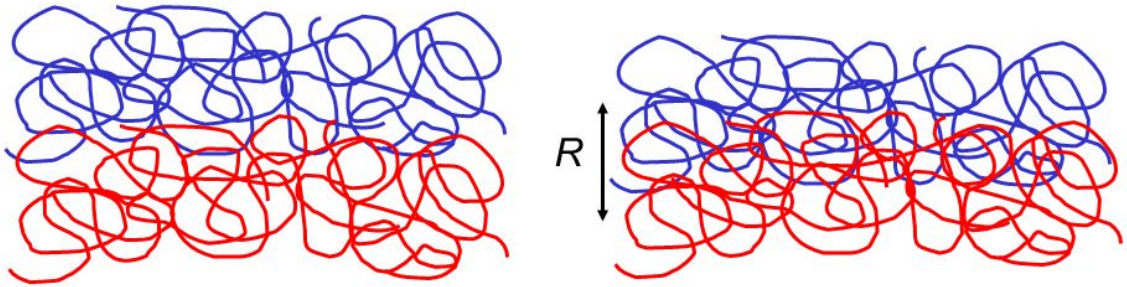
Diffusion

Diffusion Adhesion

Definition:
Creating an IPN (Inter Penetration Network) thru swelling and co-mingling with the film resins (entanglement) which in turn forces a mechanical style interlock adhesion on a molecular level to exist.

How to Enhance:

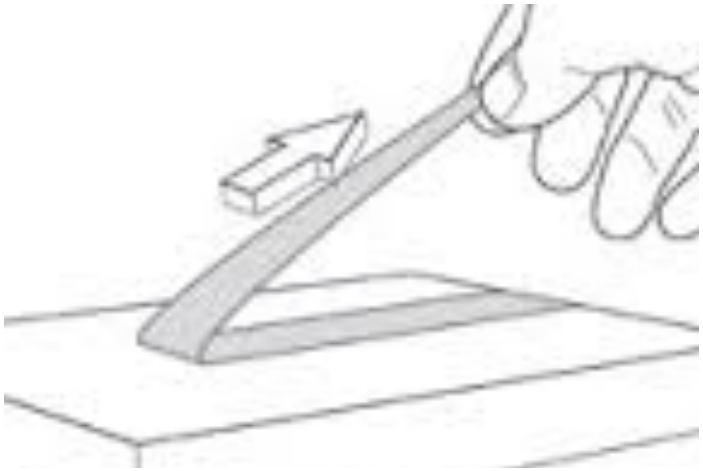
- High Swelling Solvents / Monomers
- Dwell time prior to drying / reacting (cure speed)
- Heat
- Top Coating (BOPP) on Films

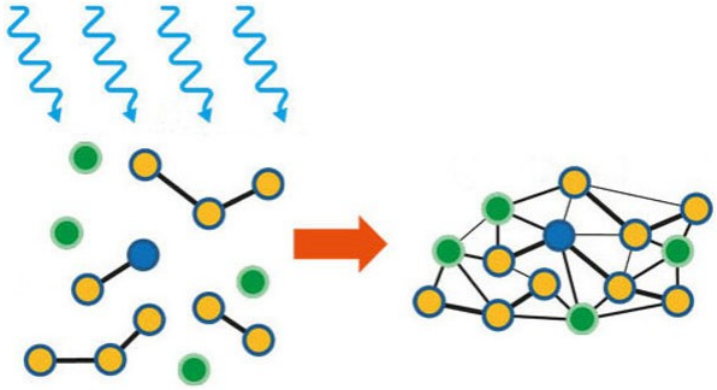


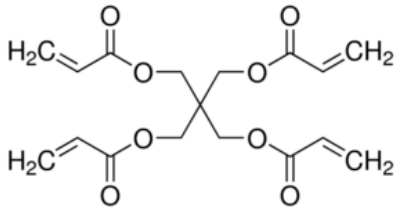
Elongation in Polymers

Elongation in Polymers allow for the following:

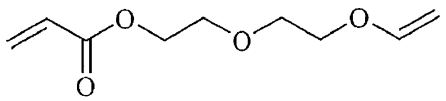
- Less micro-fracture in the tape pull. More hold from surrounding areas.
- Less stress during shrinkage in UV curing or post catalyzation (pulling away from the stock)
- In UV you're building the polymer length as you go. Heavy functionality can lead to brittle inks with poor adhesion traits. Functionality needs to be set with proper elongation factors.







High Functional Acrylate - Brittle



Lower Functional Acrylate - Softer

QUALITY CONTROL OF ADHESION

CURE

Is it dry?

Solvent Rub Resistance
(UV or catalyzed
conventional ink)

Water Rub Resistance
(WB ink uncatalyzed)

FUNCTIONALITY

Does it stick?

Standard Tape Test
(which tape)

Crosshatch Adhesion (to
what level)

DURABILITY

Does it work?

Crinkle Resistant
Scratch Resistant
Rub Resistant
Shrink Test (shrink films)

SIEGWERK

CURE

Is it dry?

Hammer Rub Test

Definition:
The inks ability to resist chemical solvation is correlated with crosslink density.

How to Test:

- 2lb. Ball Peen Hammer soaked in chemical. Rubbed back and forth with no pressure until ink film breaks. Q-tips also used at times.
- IPA recommended for UV inks, MEK for UV Coatings and 2K coatings.
- Coordinate press speed, lamp intensity or air flow with optimal hammer rubs for cured ink.
- Thicker prints, flexible or inflexible polymers and level of crosslinking all determine the amount of rubs. No magic number.

FUNCTIONALITY

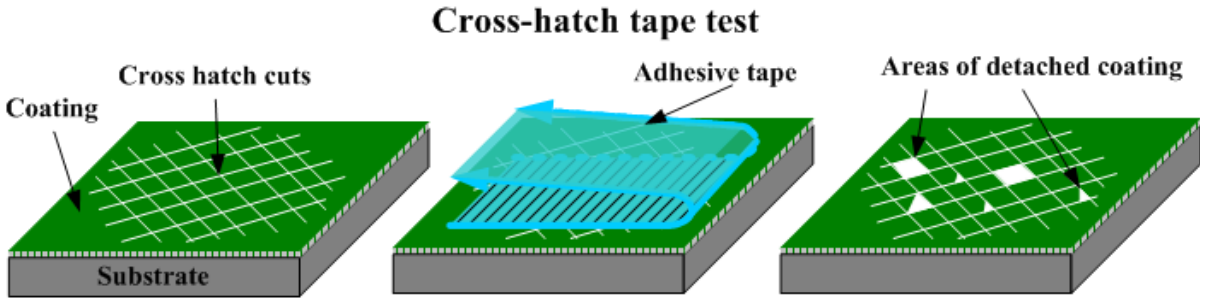
Does it stick?

Tape Adhesion Test

Definition:
The inks ability to resist tape removal after proper cure or dry time.

How to Test (2 methods):

- Standard – Tape laid on print surface and rubbed under pressure for 2-3 seconds. Fast pull is then performed. Record percentage of removal.
- Crosshatch – Ink/Coating film is cut criss cross style. Tape is then laid on the surface with pressure for a 2 second dwell and then removed fast pull. Record percentage of removal. More aggressive test which mimics diecut chipping.
- Tape – 3M 600 Tape recommended for it's ability to wet lower dyne inks more effectively (removes tape fooling).



Does it work?

Crinkle Resistant
Scratch Resistant
Rub Resistant
Shrink Test (shrink films)

Durability Test

Definition:
Direct performance testing. Ex. Does the ink shrink well with the shrink film. Will it not scratch off when packed and shipped with other containers.

Various Methods:

- Nickle Scratch – Nickle is positioned straight up under light pressure and rubbed until ink/coating film break from substrate. Amount of double rubs are recorded.
- Bicycle Crinkle – Print is held in both hands and wound up in a bicycle motion forward and reverse several times. Amount of ink removal from substrate is recorded.
- Many others