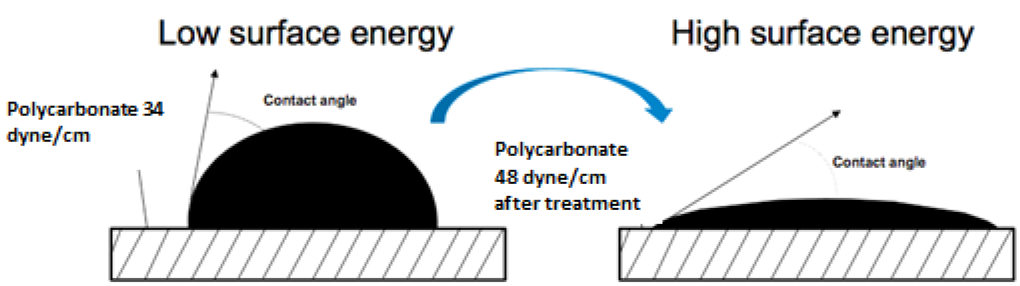
PLASKOLITE

DIGITALLY PRINTING WITH UV LED CURED INKS ON POLYCARBONATE

Digital printing offers several advantages over screen printing, including: low setup cost, higher multiple color flexibility and better quality photographic prints. Recent adaptation of digital printing to plastic substrates has met challenges, especially for UV curing ink systems that use LEDs as the UV light source.

As the industry moved to new printers, using UV LED curing systems, some end users have reported ink adhesion issues when printing on polycarbonate. Investigations have shown the problem to be intermittent with the highest failure rates on white and black inks.

Plaskolite has investigated several polycarbonate sheet samples from different manufacturers using Scanning Electron Microscope (SEM) topography observations, dyne level examinations, contact angle analysis, resin formulations and protective masking configurations. From this, the greatest differences between adequate and poor adhesion substrates were determined to be dyne levels and contact angles measurements – i.e. the “wettability’ of polycarbonate.



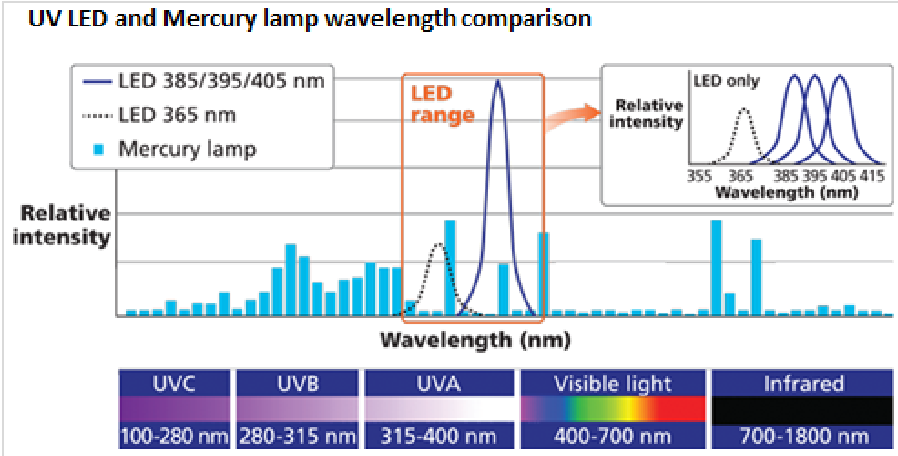
Overemphasized representation of Tuffak® Polycarbonate’s surface energy before and after treatment.

Polycarbonate sheet has been widely used as a substrate for solvent-based and mercury arc lamp UV cured printing inks for decades without issue. It is suggestive that UV LED cured systems require the substrate to have higher surface energies to obtain an acceptable adhesion level that traditional solvent or mercury lamp UV-arc inks already provide.

Thermal cure or solvent based systems achieve good adhesion because the higher solvent content acts to swell (partially dissolving the plastic surface) allowing the ink molecules to penetrate in the plastic, sometimes referred to as “getting a good bite”.

The difference in adhesion performance of UV inks cured with arc lamps versus LED lamps is an ongoing investigation. One theory suggests, in addition to curing the ink, UV light increases the surface tension of the plastic surface. Arc lamps produce a higher average light intensity across the entire UV range, and thus have more light energy to affect the surface energy change. LED UV sources provide high intensity UV light, but at a narrow wavelength distribution. The inks are designed to efficiently cure using the UV LED light wavelength, effectively absorbing the UV light energy. However, once the light is absorbed, less light energy remains available to increase the substrate’s surface energy. An observation that adhesion issues occur most often with white and black inks, highly pigmented colors, supports the theory as these pigments also block the UV light from reaching the substrate.

UV LED LAMP RELATIVE INTENSITY AND WAVELENGTH VS. TRADITIONAL MERCURY UV LAMPS:



Mercury UV arc lamps cover a much broader wavelength range which is believed to add to their robustness.

Surface tension testing referenced above resulted in measured dyne levels from 34 to 48. There was no correlation between dyne level and manufacturer, but dyne level did correlate with the age of the polycarbonate sheet. Dyne levels tended to start higher when polycarbonate sheet is first produced and then on average declined over a period of time. This phenomenon is known as "physical aging" and is common in various plastics. Dependent on the material, this can be due to reorientation of polar groups away from the surface or migration of non-polar additives to the surface. This reduction in surface energy over time explains the intermittent lot to lot variability observed by some end users.

SOLUTIONS - SUCCESSFUL UV LED INK ADHESION:

A range of substrate pretreatment options to increase surface tension are available. Each method employs different sources of energy, but the results are similar, they create more polar chemical groups or free radicals at the surface and increase the surface tension. However, the surface tension can decay over time due to physical aging (as discussed above) so the pretreatment is most effective if performed just prior to printing.

CORONA DISCHARGE TREATMENT:

During a corona discharge treatment, electrons are accelerated into the surface of the plastic through ionized gas (plasma). These high energy electrons can cause chemical bonds of polycarbonate to rupture, yielding free radicals and a higher concentration of polar groups at the surface. Ionization of the air also creates highly reactive gases such as ozone (O_3) that oxidize the surface to create polar chemical groups.

MERCURY UV ARC LAMPS:

A quick dose of UV light can serve as a good adhesion promoting pretreatment. The high energy of UV light breaks chemical bonds near the substrate's surface to create polar chemical functional groups which aid in promoting good adhesion.

FLAME TREATMENT:

Oxidizing flame exposure has been used to increase surface tensions of plastic substrates. The air to gas ratio and the addition of oxidizing agents to the gas are reported to be key variables. However, applying the flame treatment uniformly over the substrate can be a challenging.

SOLVENT WIPE:

Wiping the surface prior to printing has been successful and promoting adhesion at some end users. Similar to using solvent based inks, a solvent wipe can swell the plastic surface to help the ink to "bite" into the surface. A solvent wipe can help to remove potential contaminants that may interfere with adhesion.

ADHESION PROMOTERS:

Liquid applied adhesion promoters are commercially available. The mechanism of adhesion promotion ranges from surface swelling via a solvent to oxidative reaction to form chemical polar groups.

PRINT SPEED:

Reducing the print speed can also help ink adhesion as it gives the LED lights greater time (higher UV dosage) to perform the curing process. Ink that is not fully cured can lead to poor cohesive strength of the ink. This will be most pronounced deeper into the ink layer (next to the substrate) as the top layers absorb some, most or all of the UV light. Ink thickness is thus also important.

SUMMARY:

End users digitally printing with UV-LED cured ink systems have encountered intermittent issues when printing on polycarbonate. This emerging technology has not yet evolved to be as robust as solvent based ink systems or UV arc lamp cured systems.

The surface tension of plastic substrates is a known factor in ink adhesion and likely plays a role in some of the failures. The surface tension of polycarbonate has been observed to decrease over time. This is not specific to polycarbonate as many polymers undergo surface migrations to decrease the surface tension. Decreasing surface energies/dyne levels are inherent to the aging process of polycarbonate sheet and are not restricted to any one brand or manufacturer of polycarbonate.

Several techniques are available to increase surface tension and promote adhesion.

SOURCES:
Technical Support:
HP Printers, 3M Inks, Durst Printers, EFI Inks, UV Integration, Sun Chemical Inks, DigiTech Solutions Group

References:
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