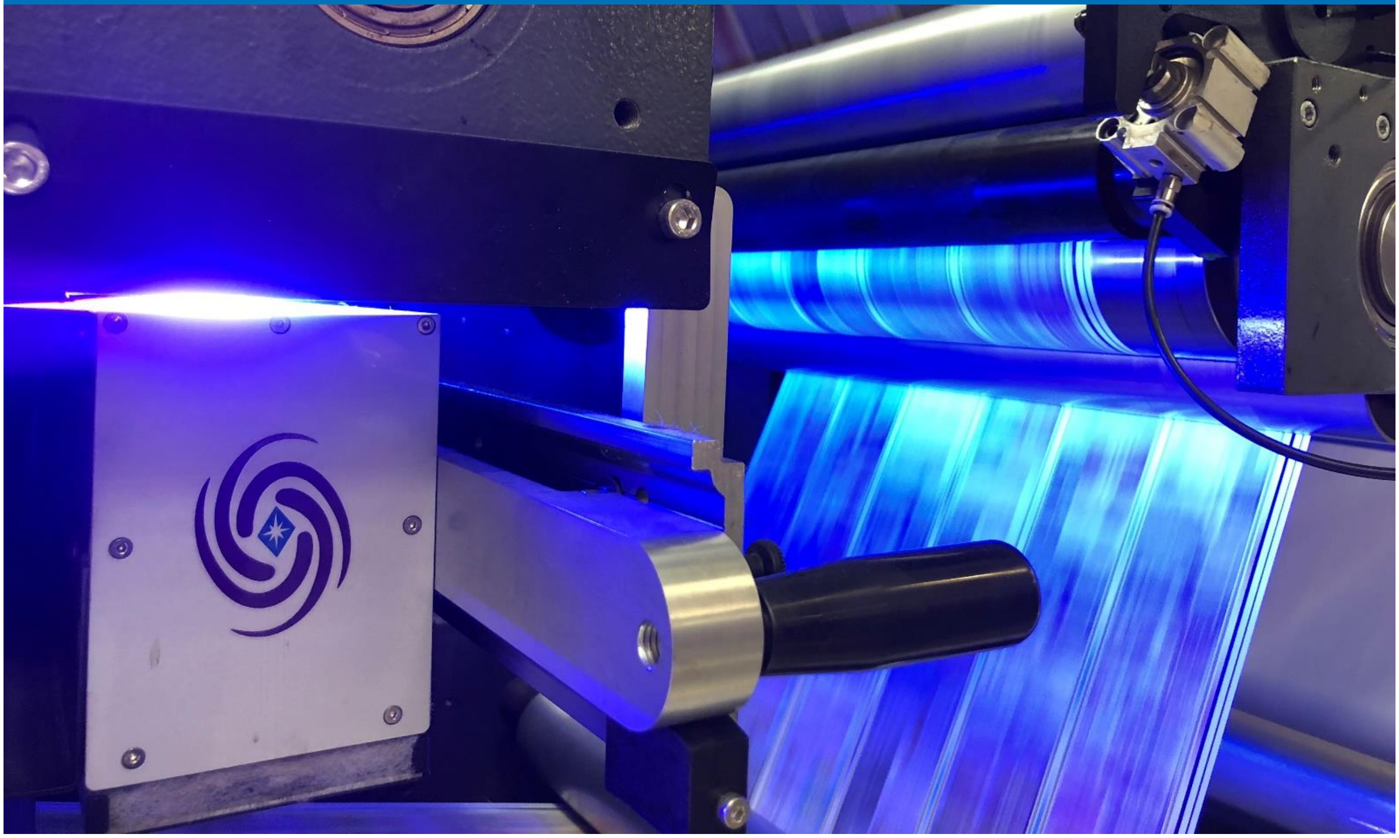
Key Applications Where UV LED Curing Outperforms

Finding the Optimal Path to UV LED Curing

A Phoseon Technology White Paper

May 2020



Overview

Imagine two very similar paths headed in different directions but ultimately ending at the same destination. How do you decide which one to pursue, and how do you identify and evaluate tangible differences along the way that may not be obvious from the start? Now imagine that one of the options is very familiar and well-used, while the other is much more enticing but a bit uncertain and less traveled. Do you follow gut instincts and fearlessly charge ahead in one direction, or do you find yourself stalled with indecision? Maybe you take time to employ the latest decision-making toolkit designed to systematically and strategically compare both options in order to reveal the more suitable choice, or perhaps you are content letting others figure everything first before following their lead later. In cases where the optimal path is not clearly known from direct experience or conclusively broadcasted by those who previously forged ahead, it is often necessary for decision makers to proceed partway in order to personally collect and verify relevant information. In doing so, one path generally emerges as the preferred alternative which ultimately builds confidence in the required course of action and simultaneously minimizes risk over the remaining journey.

You may be wondering what this dual path analogy has to do with UV LED technology and narrow-web converters? For starters, it illustrates how indecision, lack of confidence, and scant testimonials in the marketplace can weigh on unfamiliar users during the early decision-making process. This causes many to erroneously and prematurely discount the viability of UV

LED technology when compared to conventional mercury lamps. In order to overcome this hurdle, converters should proactively advance partway in order to learn what is indeed possible for their own set of circumstances. In fact, many successful businesses are built on a series of smaller steps that collectively work to propel organizations forward through unknown territory while simultaneously providing opportunities for both correction and acceleration along the way.

If you are a narrow web converter interested in UV LED curing but unsure how to proceed, a great place to act is in areas where scientific principals naturally allow UV LED systems to outperform mercury systems. Focusing on specific aspects of UV LED technology that are uniquely suited for labels and flexible packaging is a more manageable and effective endeavor for those new to the technology than trying to tackle everything all at once. With the technology broken into a few smaller pieces, it is then much easier to analyze and learn how those pieces can directly impact a converter's bottom line.

Applications, such as the one shown in Figure One, where UV LED technology is vastly superior to mercury systems include the curing of black, white, and metallic inks as well as laminating and cold foil adhesives. The critical element that each of these has in common is the requirement that UV energy travel through dense pigments, additives, or films without being redirected or prematurely absorbed before full cure is achieved. Due to the physics of light and nature of UV LED output, depth of penetration is exactly where LED technology excels.

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Figure One: Phoseon FireJet™ FJ605 UV LED Curing System on Flexo Press Printing

Ultraviolet Light's Depth of Penetration by Bandwidth

Regardless of how UV output is generated, longer UV-A (315 – 400 nm) and UV-V (400 – 445 nm) wavelengths penetrate deep into inks, coatings, and adhesives while shorter UV-C (200 – 280 nm) wavelengths are absorbed at the surface. In terms of curing, UV-A and UV-V produce through-cure while UV-C is responsible for activating the layer of chemistry exposed to atmosphere. A lack of through cure can leave formulations soft and can contribute to inadequate adhesion at the bottom film or construction while insufficient UV-C can leave formulations feeling greasy or tacky to the touch. The relationship between wavelength bands and depth of penetration is illustrated in Figure Two.

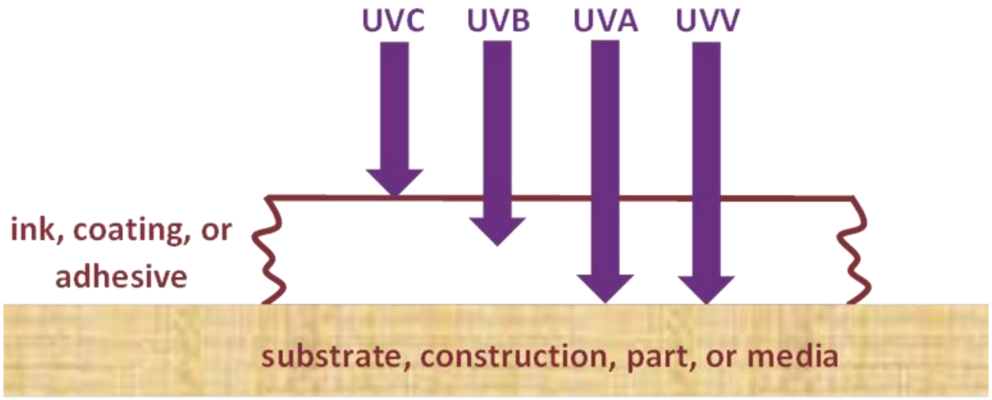

Figure Two: UV Wavelength Penetration through Inks, Coatings, and Adhesives

Conventional mercury lamps are broadband sources (UV-C, UV-B, UV-A, UV-V, visible and infrared) while UV LEDs are concentrated emitters of longer UV-A (385 and 395 nm) and UV-V (405 nm) output with UV-C devices currently in development. To compensate for the absence of UV-C, today's LED lamp heads are engineered to provide a much greater power output than mercury lamps. This power output is referred to as irradiance or intensity. At greater levels, intensity aids in curing the exposed surface of the formulation to reduce or eliminate the greasy or tacky feel. It also helps more of the UV light penetrate further into inks, coatings, and adhesives.

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Black, White, and Metallic Inks

Non-soluble pigments and soluble dyes are additives that formulators use to give inks color. Both types have inherent optical properties that negatively affect the ability of ultraviolet light to travel through chemistry. In the case of dyes, absorption of UV light is the main obstacle. For pigments, absorption, scattering, and reflection as well as particle shape and size all have the potential to greatly impact and diminish cure.

In general, absorption causes UV energy traveling through chemistry to be transferred to the interfering molecule. Scattering results in light deviating into multiple different directions, and reflection off a smooth surface forces all wavelengths to be redirected at the same strike angle. All three contribute to a significant reduction of UV intensity and depth of travel. This means there is less energy available for absorption by photoinitiators, particularly those furthest from the light source. When photoinitiators are forced to compete with pigments and other additives for a limited amount of incident light, cure is diminished, quality and yields are sacrificed, and the press line speed must often be slowed in order to increase exposure time. As a result, curing of heavily pigmented and thick printing inks has long been one of the greatest challenges for mercury UV lamps.

While each additive in a formulation uniquely reduces the transmission of light, pigments such as carbon black, metallics, and white titanium dioxide (TiO_2) have the biggest impact. These pigments are used in different concentrations to create process, line, and high-density inks. Since greater concentrations of these pigments significantly impede cure, it is critical that converters follow the recommended anilox BCM and line count recommendations provided by ink suppliers.

Carbon black pigments are widely used by formulators since they provide high light and weather durability along with superior color strength even at low concentrations; however, the particles readily absorb energy across the ultraviolet and visible light bands. As a result, formulators must be careful in balancing carbon black's particle size, concentration, and opacity with the ability of UV light to penetrate. While metallic pigments fully block UV light, they also serve as tiny mirrors dispersed throughout the formulation. The result is wide light scattering. This reduces the total energy that reaches the photoinitiators but also has the positive effect of redirecting some UV light toward shadowed photoinitiators. Finally, titanium dioxide pigments used for white inks filter all wavelengths below 380 nm while allowing longer wavelengths to pass. Since UV LED curing lamps are predominately 395 nm, UV LED output is not affected by the TiO_2 pigments. Using LED technology, therefore, enables UV energy to penetrate all the way through white ink with little to no absorption.

Due to longer UV-A (395 nm) wavelengths as well as intensities that are four to eight times greater than mercury lamps, UV LED technology always improves the cure of UV LED formulated carbon black, metallic, and white inks when compared to mercury lamps. The longer UV LED wavelengths naturally penetrate deeper, and by starting with a much higher irradiance, even if intensity diminishes as light travels through the formulation (due to absorption, scattering, and reflection), more light is still reaching the substrate. For label and flexible packaging applications where black, white, and metallic inks represent process bottlenecks, switching to a UV LED process with its ability to penetrate deeper into the ink will result in increased press speed, more opacity, stronger color, greater adhesion, better cure, greater yields, and less scrap.

Figure Three illustrates a strength of cure comparison between a 24 Watts/cm^2 Phoseon FL400 UV LED system at 395 nm and a conventional 500 watts per inch (wpi) mercury lamp emitting intensities of around 3 Watts/cm^2. Both lamps were used to cure a dense black ink using anilox BCMs of 2, 3, and 4 at web speeds of 200 fpm. Regardless of ink laydown, the Phoseon UV LED system generated significantly better surface and through cure than the mercury lamp. This was quantified using IPA double rubs where the LED system yielded 34 to 90% more double rubs than the mercury lamp across all three film thicknesses. It should be noted that as ink laydown increased from 2 to 3 to 4 BCM, the UV LED

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system performed increasingly better against the mercury lamp. This reinforces the fact that mercury lamp output with its lower intensity and broadband spectrum is less effective at penetrating densely pigmented inks, particularly those with greater film builds. Conversely, UV LED wavelengths at 395 nm naturally provide increased through cure which is particularly beneficial for thicker and denser carbon black inks.

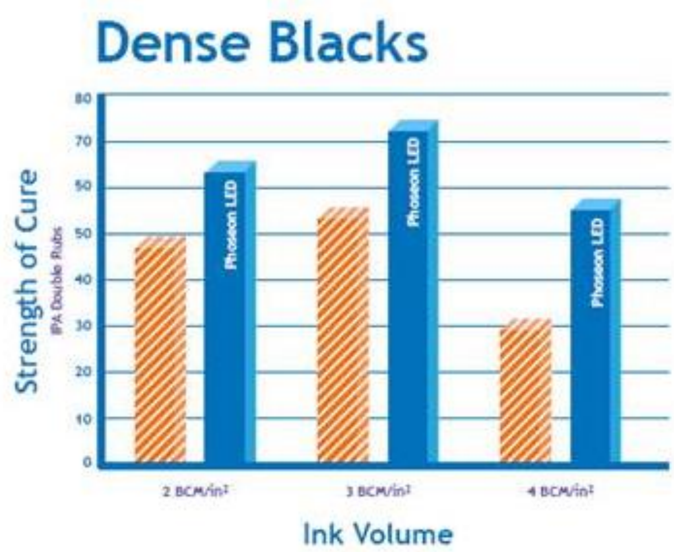

Figure Three: Strength of Cure Comparison for Dense Black Inks – Mercury UV vs UV LED

Laminating and Cold Foil Adhesives

Laminating adhesives are used in flexible packaging and labeling applications to securely bond two or more flexible constructions such as PET, PE, PP, paper and foil. The adhesive is applied to the substrate with lower absorption properties before being nipped to the second substrate and passed underneath a UV curing lamp for instant cure. In the case of laminating adhesives, the two substrates are permanently bonded; whereas, for cold foil, the transfer film is unwound after cure leaving the decorative foil only in locations where the adhesive was applied.

Adhesives rarely contain dyes or pigments that absorb, reflect, or scatter UV light; however, they are typically applied at thickness that are greater than those used with inks. As a result, the longer UV-A wavelengths and higher intensity emitted by UV LEDs enables better depth of cure than can be achieved with mercury lamps. In addition, the longer, near visible output of UV LEDs is advantageous in the case of laminating and cold foil adhesives since the UV energy must first pass through a film or foil construction in order to reach the adhesive. Longer UV-A and UV-V wavelengths have superior luminous transmittance through materials compared to shorter UV-B and UV-C wavelengths. The fact that the adhesive is cured between two films also eliminates any need for UV-C wavelengths as none of the adhesive is exposed to oxygen which can inhibit cure.

In all cases, UV LEDs are significantly more efficient and effective at curing laminating and cold foil adhesives than mercury lamps. In addition, when compared to solventless chemistry, UV cured laminations and cold foils can be immediately processed following exposure. The one to three day curing time required with solventless adhesives is completely avoided with a UV process.

> *"Energy density, also known as dose or radiant energy density, is the energy arriving at a surface per-unit-area during a defined period of time."*

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Ways to Further Minimize Risk while Pursuing UV LED Curing

For converters not entirely convinced that UV LED curing is the right choice for black, white, and metallic inks as well as laminating and cold foil adhesives, there are other ways to minimize risk while exploring the technology. First, work with an established UV LED system supplier such as Phoseon Technology who offers proven products and a broad range of liquid-cooled and air-cooled offerings that can be suitably matched to specific process needs. If you are not in a position to convert the entire press to UV LED, a few air-cooled LED lamp heads can be integrated and later expanded to more stations. A global support team such as the one offered through Phoseon Technology is also available to provide integration, application, and field service as needed. Finally, establishing a strong partnership with a UV LED system supplier, formulator, and press OEM will facilitate collaboration and development. In order to build confidence in the proposed LED solution, samples can typically be run with your desired substrates, constructions, and formulations on either a customer demo press or even your production line using loaner lamps.

For black, white, and metallic inks as well as laminating and cold foil adhesives, the higher irradiance and ability of UV LEDs at 395 nm to penetrate deep into the chemistry makes the technology ideally suited for label and flexible packaging applications. The long life and reliable output of UV LED lamps also provides consistent cure and stability of process.
This translates into improved up-time and predictability of cure which benefits all who are involved. Since UV curing issues on press are typically the result of a faulty mercury lamp, the formulation, or the converting process, the use of UV LED technology eliminates the UV curing system as the source of the problem. This saves time in troubleshooting and ultimately has a positive impact on the bottom line. Plus, it's important to keep in mind that all the other amazing benefits of UV LED technology

such as reduced heat transfer, instant On/Off output, elimination of ozone and mercury, no air-extraction, reduced maintenance, zero bulb and reflector changes, and energy savings during operation always apply for every application.

If you find yourself intrigued with UV LED curing, consider adopting the technology for curing black, white, and metallic inks as well as laminating and cold foil adhesives. This is the best way to become familiar with what is possible and demonstrate first-hand the many ways in which UV LED systems are superior to mercury arc lamps. In addition, focusing on proven applications where UV LED is scientifically the better choice minimizes risk associated with equipment and formulation changes.

Instead of waiting for others to communicate their own UV LED success stories before you proceed, proactively advance partway to learn what is indeed possible for your own set of circumstances. By embracing UV LED technology for the ink and adhesive applications described in this paper, you can strategically break from the pack of hesitant converters waiting for everyone else to move first and confidently proceed down the optimal path to better printing and converting with UV LED technology!

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About Phoseon Technology

The world leader since 2002, Phoseon Technology pioneered the use of LED technology for Life Science and Industrial Curing applications. Phoseon delivers innovative, highly engineered, patented LED solutions. The company is focused 100% on LED technology and provides worldwide support.

Contacts

For more information about Phoseon Technology suite of products, visit **http://www.phoseon.com/** or call **(503) 439-6446**

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