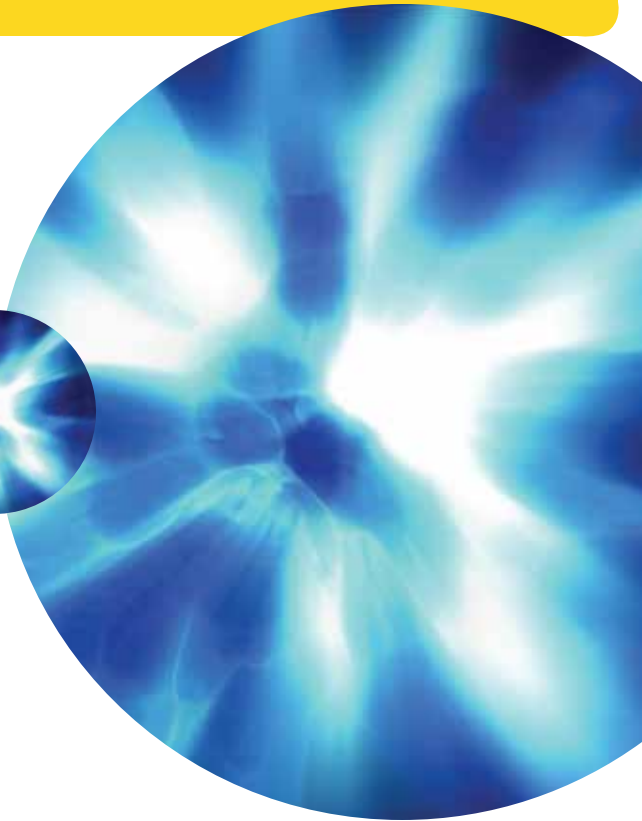
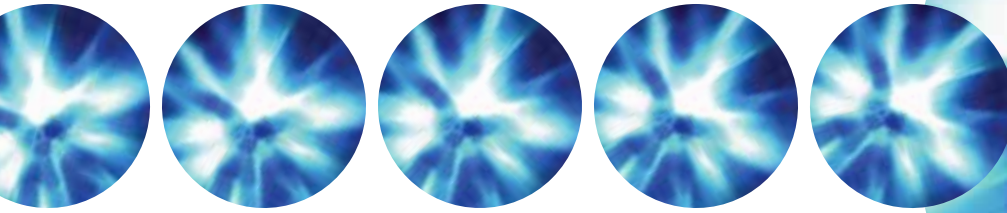


LED UV Curing in Wide-Format Digital Printing



When you hear UV, do you first think of sunscreen and sunny beaches? If you own one of the estimated 10,000 UV wide-format printers installed in the world today, probably not. Or, maybe you are considering joining this group's ranks — it is the fastest growing segment in the wide-format print industry.

The rapid ascent of UV in our industry will likely continue, given the many advantages UV curing provides. Outside the print world, another major change is happening from traditional light sources to LEDs. The little indicators on your TV remote control have evolved and now challenge incandescent and fluorescent lights in general lighting applications. Looking forward, UV LED technology is poised to take on UV arc lamps for the next generation of UV light applications. This changing reality has significant implications for print shops and printer manufacturers alike. Over the next few years, you can expect to see some big changes in the “wide-format” printing industry from printer applications and capabilities to more cost efficient operations and increased ease of use.

LEDs, short for “light emitting diodes,” have seen tremendous advances in technology over the past 15 years. Billions

of dollars have been spent researching and improving LEDs, driven mainly by the desire to replace traditional incandescent and fluorescent lights with a more energy efficient and environmentally-friendly alternative. This has created an explosion in capabilities, with the light produced by LEDs doubling roughly every 18 months and a reduction in the cost per watt of light. UV LEDs also benefited from this research to the point that they now achieve the curing efficiencies required for some wide-format printing applications. A small number of these printers are already commercially available and more are expected. But what are LEDs and how do they stack up against the incumbent mercury arc lamps? What are the technology hurdles for implementing them into wide-format printers today and when will these hurdles be overcome?

UV digital printing has grown quickly and taken a central place in the graphics business. According to industry analysts IT Strategies, 17 percent of all wide-format printed material is done on UV digital printers and that number is expected to climb to 28 percent by 2012. This increase is being driven by the growth in the install base of printers, which is climbing at 16 percent a year. UV digital printing

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Property	Cure Properties Impacted	Comment
Light Spectrum	Surface, bulk and adhesion	Match with ink
Optical power	Degree of cure achieved	Threshold defined by application (ink, process speed, coverage)
Irradiance/beam shape	Balance achieved between surface, bulk and adhesion	Match with ink
Light output maintenance (over time)	Cure consistency as light source ages	Varies by type of source

Figure 1: UV Light Source Properties and their Connection to Ink Curing

Over the next five years, we will see UV LED curing integrated into higher productivity and higher end printers.

offers some great advantages — substrate versatility on the same printer, enhanced productivity through fast drying times and reduced need for lamination and lower running cost efficiencies with lower ink costs per print. In addition to these, UV digital printing has opened up new opportunities and applications such as durable, printed ceramic tiles and flooring.

The Essence of UV Printing is the Cure

Critical to the success of a UV printer is how well the ink is cured. Even the term “cure” can mean different things to different printers based on application. For instance, is the image being printed on a rigid or flexible substrate, for indoor or outdoor use? Figure 1 shows some of the common associations that the UV curing business makes between arc lamps and the cured ink. For UV LEDs to be successful in this industry, they must provide either an equivalent or better cure for all current applications.

Technology: Arc Lamps Versus LEDs

The UV digital wide-format printing industry has grown up using arc lamp technology borrowed from the older UV technologies of the screen and flexographic industries, with only a few adjustments. Arc lamps produce light by exciting a super heated plasma consisting of mercury and fill gases, all contained within sealed quartz tubes. The excitation is provided either by an electrical discharge (a current running through the plasma) or via microwave excitation. The mercury atoms in the plasma absorb energy from the electrical current or the microwaves, and then release that energy in the form of light. This all happens at temperatures over 1,000 degrees Fahrenheit, so considerable excess heat is generated in the process. The light created by the arc lamp spans the spectrum from deep UV through the visible range and into the infrared region. Of course, only the UV portion contributes to the cure of the ink. Optical reflectors are used to collect as much of the generated light as

possible and direct it onto the substrate.

Arc lamps can produce a lot of UV light. This is why they are the standard use today. The broad UV spectrum they produce has allowed the creation of ink chemistries that are versatile and cure well. It is a reliable, mature technology that is well accepted.

On the downside, arc lamps require that certain accommodations are made to the printer architecture and, furthermore, they place some restrictions on applications. First, they produce a lot of heat, which must be managed within the printer. Some of this heat is transferred to the substrate, which can cause issues for temperature-sensitive materials. Second, cooling the lamps requires substantial airflow within the printer. This adds additional complexity to the printer design. Sophisticated electronics are required to ignite the lamps and keep them running in a stable manner. High power arc lamps, such as those found on grand format printers, produce ozone a potentially dangerous gas that requires special venting. Finally, arc lamp output degrades over the lamps’ 500 to 1,000 hour lifetime by as much as 50 percent. This introduces risks to print consistency.

LED Technology

An LED is a semiconductor device that converts electricity into light. LEDs were developed in the 1960s, shortly after the invention of the transistor. Originally used as indicators or low power illumination, they are just now beginning to find application in general illumination and in the more specialized fields of photo activated material processing such as ink curing and high brightness specialty illumination.

LEDs were first developed in semiconducting materials, the same type of materials used to create transistors and microprocessors. By engineering the properties of the semiconductors, it is possible to convert electrical current into light and heat. With the best devices today, up to 20 percent of the input electrical

power can be converted to light; the rest of the energy turns into heat and must be extracted so that the LED is not damaged by getting too hot. The light generated is concentrated in a narrow region of the UV spectrum in contrast with arc lamps which generate a full spectrum of UV to infrared light. It is this narrow spectrum of UV light generated by LEDs that leads to one of their key advantages — cool cure. It was the development of high power LEDs and, in particular, high power UV LEDs in the late 1990s that enabled applications such as UV ink curing in wide-format printers.

LEDs have numerous advantages when compared with arc lamps (see Figure 2). First and foremost is the concentrated spectral content of the light generated. Since the optical spectrum is limited to what the process requires, namely the UV range for ink curing, the electrical to optical conversion efficiency is substantially improved over arc lamps. Recall that with arc lamps, only a portion of the light generated is UV. Much of the generated optical energy does not contribute to the process.

In some instances, if this additional optical radiation is not filtered out, it can cause unwanted secondary effects such as sample heating. The higher effective electrical to optical conversion efficiency of LEDs means sufficient optical energy for the process can be generated with less electrical input. As a result, there is less wasted energy to deal with. In the case of LEDs, the wasted energy comes also in the form of heat. The lower overall heat load for the LED system enables more compact system designs without the need for complex igniter electronics present with arc lamps.

Other advantages inherent to LEDs include a life up to five times longer than arc lamps. This leads to an overall lower cost of ownership for this technology. In addition, it is possible to switch LEDs on and off very quickly, thus eliminating the need for internal or external shutters. The optical output of LEDs can be controlled by varying the electrical drive signals that allow for electronic intensity control. This removes the need for shutters, which further simplifies system design and improves product reliability. And, due to their higher effective efficiency and their lack of mercury, LEDs are more environmentally-friendly than arc lamps.

LEDs are, however, not without their limitations and this explains why they have not yet found widespread adoption. The most significant limitation of LEDs also is its key strength, namely the narrow

UV LED Benefits for Digital Printing	
Features	Benefits
Cooler cure (no IR)	Allows printing on heat sensitive substrates
Long lifetime (>5000 hrs)	Lower operating costs, simplified maintenance
Air cooled	Simplified printer architecture
Instant on/off	No warm-up or cool-down time, simplified mechanical design (no shutters)
Environmentally friendly	No Hg, Ozone, lower energy consumption
Simplified electronics	No high voltage ignition, reduced cost for printer electronics and shielding

Figure 2: UV LED Benefits

emission spectrum. Recall from Figure 1 that a broad UV spectrum is needed for conventional UV digital inks to achieve good cure. These inks have been tuned to respond to the broader mercury spectrum. The limited spectrum of LEDs can cause problems with these inks, such as insufficient cure, leading to tacky surfaces or adhesion problems. Even if full cure is achieved, the cured properties of the ink may be different with LEDs compared to arc lamps.

Until recently, an equally problematic issue with LED technology was the maximum irradiance or optical power density that was achievable on the printed substrate. To achieve a good, tack-free surface, regardless of whether using an arc lamp or an LED, it is necessary to concentrate sufficiently the optical energy on the substrate. Arc lamps have ample energy. For example, a six or ten inch long arc lamp rated at 600W/inch of electrical power consumption can easily produce an irradiance in excess of 10W/cm² through the use of parabolic or elliptical reflectors. This is more than sufficient to achieve good surface cure. The situation with LEDs is somewhat different.

High power UV LED systems are comprised of arrays of individual LED semiconductor chips called “die.” (see Figure 3)

“High power” LED die measure approximately 1x1 mm² and produce up to 0.5W per device. In principle, if we could pack these individual die side by side like mosaic tiles, we would be able to achieve radiated power densities of up to 50W/cm² — even more than that achievable with arc lamps. Practical limitations related to cooling the LEDs, getting electrical current to each device and extracting efficiently the light created by each LED had limited the irradiance to about 4W/cm². This level has proven marginal in achieving good surface cure. For some printing applications it is sufficient, while



Figure 3: Arrays of Individual LED Semiconductor Chips

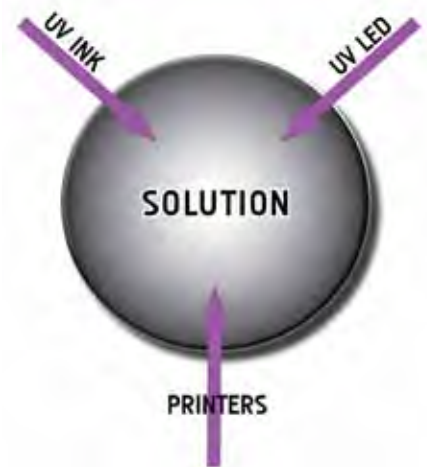


Figure 4: The Three Technology Vectors

for some, it is not.

More recently, high power LED arrays with power densities of 8W/cm² have become available and there is talk within the LED community of 12 and 16W/cm² arrays in the research and development phase. Although these arrays promise to solve the irradiance challenge, they come with some cost. It is necessary to use liquid cooling with such arrays in order to manage the waste heat created. On wide- and super wide-format printers, this means added complexity to the printer architecture due to the addition of another liquid handling system and a chiller.

Many UV ink suppliers have weighed in on this issue and created new formulations of ink that have a tailored response to UV LED light. This is a challenging task given the many qualities for which the post-cured ink must be optimized — color gamut and stability, solar resistance, adhesion, surface and bulk cure, flexibility/rigidity and odor. Their efforts have resulted in inks that require less overall energy to achieve full cure, by up to a factor of three in some cases, and that can have the surface and adhesion properties desired with an LED spectrum. These new inks have become available only in the past eighteen months.

The final issue limiting the adoption of LED systems into UV digital printers is acquisition cost. As a new technology, UV LED systems in general are more expensive than arc lamps. The cost of an LED system depends strongly on the number of LED die used to fabricate the array. The size of the array depends upon the print swath and print speed, with narrower and lower productivity printers requiring smaller arrays. LED cost also depends on the specific type of UV LED die used. Inks tend to cure more efficiently with light from the deeper portion of the UV spectrum, but this requires a more expensive type of LED. Overall, however, the cost of UV LEDs is trending downward and has dropped by more than a factor of ten over the past ten years.

Much of the upfront acquisition cost of UV LED systems can be offset by the advantages they bring, both from the perspective of the printer manufacturer and from the print shop owner. Printer architectures can be simplified, reducing overall system costs. Once in the field, UV LED curing systems will have lower running costs and provide shop owners with energy savings. Due to the long life of the LEDs and the reliability of this solid state technology, service and maintenance costs will be reduced, not to mention the fact that it will no longer be

necessary to perform expensive arc lamp replacement every 500 to 1,000 hours of use. The cooler cure of an LED system also opens new print applications for print shop owners on temperature sensitive substrates, expanding their business potential.

Current Status and the Road to Widespread Adoption

Despite the limitations, LEDs are being used effectively. Already, pioneering printer manufacturers have introduced UV LED curing on some of their commercial systems. Examples include the Inca Spyder 150, Sun Company LLC NEO, Mimaki UJV-160 and the Roland VersaUV LEC-300.

To achieve widespread adoption of UV LED curing on wide-format printers in the future, three key requirements must be satisfied:

- Achieving equivalent ink cure without compromise
- Successfully working into the architecture of wide format printers
- Being cost effective

As discussed, the UV LED industry, in partnership with printer manufacturers and ink suppliers, is well on the way to achieving all three. Adoption will take place most likely on a printer-by-printer basis, determined by the target applications and available UV digital inks. Those print applications that have integrated LED curing to date have included lower productivity printers with narrow print swaths. For these applications, the power, irradiance and cost elements of the curing system have been optimized. Over the next five years, as the technology advances along these three vectors, we will see UV LED curing integrated into higher productivity and higher end printers (see Figure 4, page 13).

Conclusions

The digital UV wide-format market is continuing to grow strongly and it draws in new technologies as it matures. The industry stands poised to take advantage of the tremendous advances in UV LED light sources to bring the print world all the reliability and functionality they offer. This will enable a new generation of printers to print a greater range of applications and provide higher reliability, easier operation and lower operational costs. So don't think sunscreen when you hear UV, think LED!

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