LED Curing

XCURA LED

Inks designed with the future in mind!

Rely on us.

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Agenda

- What is LED Curing?
- Advantages and Disadvantages of LED Curing
- Traditional UV vs LED
- Formulations
- Target customer base
- Voice of the customer
- The Flint Group value proposition

What is UV-LED Curing?

- UV - Light Emitting Diode (UV-LED)
- UV LED is an alternative UV curing system based on solid state devices.
- Narrow wavelength band
  - Typical peak output for use in graphic arts 375nm or 395 nm.
  - Maximum bandwidth of 40 nm.
  - Other lamp outputs of 365, 350, 405, 210, 250, 275 or 290 have been produced but for speciality applications
- Power Output of LED lamps
  - UV LED lamps - Up to 16,000mW/cm2 (16 Watts/cm^2 - 395nm; 2 Watts/cm^2 – 365nm)
  - UV LED lamps deliver approx. 482.419 mW/cm^2 and 21.8mJ/cm^2 at surface of the print (10 cm from lamp housing) (300 fpm)*
  - Traditional UV lamps delivers approx. 1,648 mW/cm^2 and 74.541mJ/cm^2 at surface of the print (300 Watt/inch H-bulb at 300 fpm)*

* Lamp output measured on each type of curing unit using a EIT UV Power Puck

UV-LED Advantages

- No IR radiation and minimal heat transfer
- LEDs are more compact
- Low Voltage – simpler and safer
- Instant On/Off – No shutters are necessary (Traditional lamps require cooling down in idling mode prior to going back to full power)
- Consistent UV output over operating life
- No UVC and No ozone created – Eliminating need for exhaust.
- Does not contain heavy metals (mercury)
- Longer Life
- LEDs are more efficient than bulb technology with 15-20% of the energy applied transformed into light.
- This means that 80-85% is transferred into heat.
- Since the wattage is low, this heat is not very high.

UV-LED Disadvantages

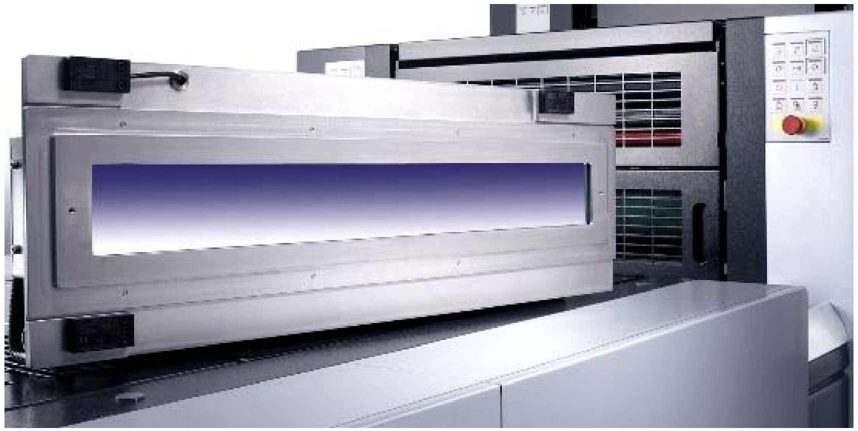
- Lack of UV light below 350 nm (majority of photoinitiators absorb in these wavelengths)
- Suitable for commercial applications only. Non food packaging application.
- If the LEDs get too hot, the lifetime is greatly reduced.
- Limited availability of semi conductors (increase in availability since 2012)
- Lamp output not sufficient at suitable wavelengths (Lamp output has achieved limited commercial viability)

Traditional UV vs. UV LED

	UV LED	UV Lamp
Size	Compact	Large
Power	70-80% Less than UV Lamp	High
Start Time	Instant On	Long
Heat Production	Low	High
Environment	No Mercury	Mercury Bulbs
Lamp Life	10,000-30,000 hours	700-2,000 hours
Dangers	Slight Skin and Eye	Skin, Eye, Voltage, Heat, Ozone, Mercury leakage
Equipment Cost	High	Std.

UV LED Lamps

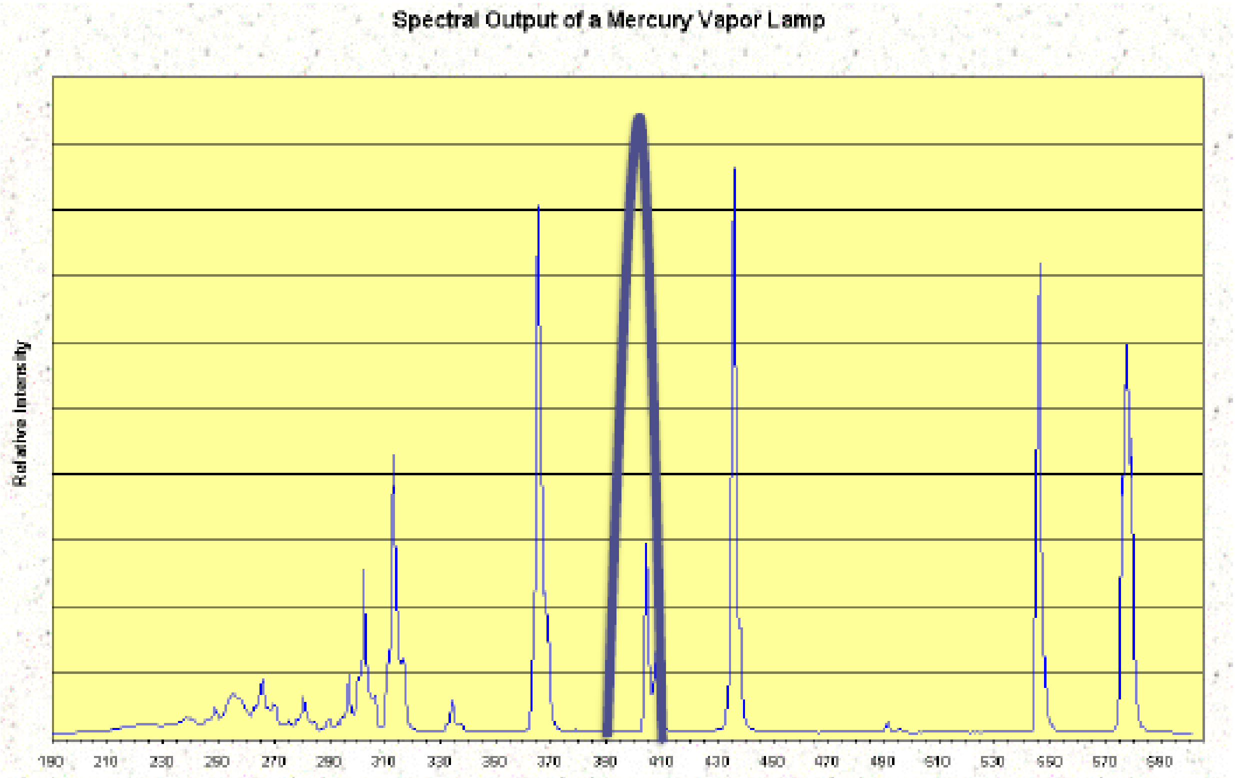
- At this time, the following companies have UV LED units which are being used on printing presses:
  - IST Metz – LUV LED System
  - Air Motion Systems – AMS LED-UV Peak Series XP Systems
  - Heraeus Noblelight (Fusion) - Noblecure
  - KBA – VariDry LED UV
  - Heidelberg – DryStar UV LED
  - Ryobi – LED-UV
  - Phoseon – Fire Series LED lamps.



Ink Formulation

- Select wavelengths that match up with the pigments used and output of the lamp.
- This requires photoinitiators which absorb higher wavelengths.
- These materials are typically 3-5 times more expensive than traditional UV curing photoiniators and makes up approx. 20-30% of the inks cost.

LED Spectral Output



The heavy blue line is the output of a typical 395nm UV LED high power lamp. The thin blue lines behind is the typical lamp output of a standard H-bulb (std. mercury vapor lamp)

Who Might Use UV LED for Graphic Arts?

- Conventional ink printer who had limited space for exhaust and lamps, the UV LED compactness leads to availability to place in small spaces and capability to print UV inks giving all the advantages of UV printing (ie. Fast turnaround, high gloss, etc.)
- Narrow Web Printing
- Commercial Printing
  - Direct mail
  - Displays
  - Cards
  - Printing on heat sensitive substrates
- Packaging
  - Printing on heat sensitive substrates
- Not recommended (presently under R&D)
  - Food Pkg. – increased amount of photoinitiators are used
  - Not recommended for extremely high ink coverage and builds without multiple lamps.
- Some companies have combined UV LED with traditional UV lamps with very good results.

General Demands & Voice of Customer

- Ability to **cure using LED** lamps
- Benzophenone, 4-MBP, ITX and HDODA free
- **Wide range of substrate** adhesion
  - Paper and Paper Board
  - Non-Porous Substrates
- Excellent **press performance**
- **Fast Cure**

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Value Proposition

The Flint Group **XCURA LED** Series Inks gives our customers the ability to print on sheetfed and web presses equipped with UV LED lamps. The XCURA Inks are designed to have **excellent cure** when using UV LED lamps.

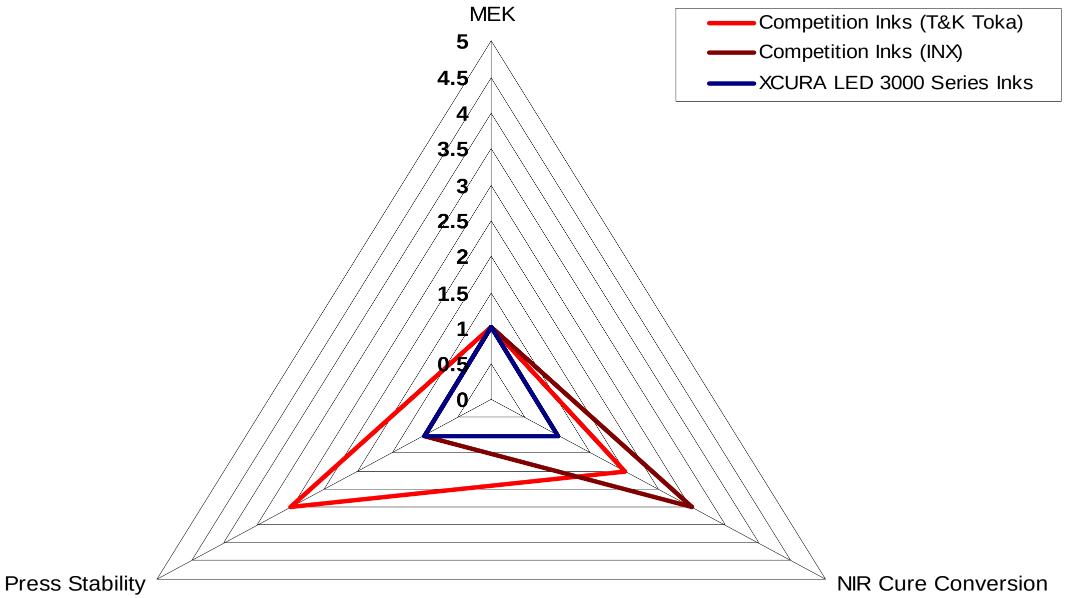
By utilising this process, our customers can **reduce cost** by:

- Reducing the **number of UV lamps** needed to cure the inks
- **Eliminating extraction**, needed for traditional UV curing (UV LEDs do not produce Ozone or high temperatures which need to be extracted)
- **Reducing the energy** necessary to cure the inks due to efficiency of UV LED lamps

Attributes and Benefits

- **Attributes**
  - Cures under UV LED lamps (380nm - 395 nm)
  - **Fast cure**
  - **Excellent Press Performance**
  - Adheres to **wide range of substrates**
- **Benefits – LED Curing Technology**
  - **No IR heat** generation and much cooler running technology than traditional UV inks
  - **Compact size** allows for easy placement on press
  - **Low Voltage** – simpler and safer
  - **Instant On/Off** – No shutters are necessary
  - **Consistent UV output** over operating life
  - No UVC and No ozone created – Eliminating need for exhaust.
  - **Does not contain heavy metals** (mercury)
  - **Longer Life**
  - **LEDs are more efficient** than bulb technology with 15-20% of the energy applied transformed into light.

Benchmark Results



Testing was conducted on a B1 4x4 prefector press. One lamp module is located after the first four colour process prior to perfecting and another lamp module is located at the end of the press. The press was run at 10,000 and 15,000 sph.

NIR Cure Conversion (Near-Infrared Spectroscopy) – Ranking is based on the amount of conversion of the acrylate bond in order of 1 = highest degree of cure and 3 = lowest degree of cure

Press Stability is based on ink/water balance on press, time to achieve density and how well it held density. (Ranking 1,2,and 3)

MEK – based on rubs with MEK

Any Questions?

For questions in EMEA region – contact Gunter Sieben-Haussen – gunter.sieben-haussen@flintgrp.com

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23rd January 2014

New UV Curing Capabilities and Technologies
The LEDgend Continues!

In this second article on new UV curing technologies, we review the advantages of LED curing in comparison to traditional UV curing.

Some of the drawbacks with traditional UV arc lamps are that the lamps contain a small amount of mercury. If they are broken, special care is needed to ensure that the mercury is contained and safely disposed of. Secondly, because UV lamps emit wavelengths in the UV region below 280 nm, ozone is produced. This requires an outside exhaust to remove the ozone from the production floor. Also, in order for the lamps to remain lit, they must stay above a minimum light intensity. Reducing the energy lower than this will result in a lamp that is not producing light. It also takes time for the UV lamps to come up to full power and, if shut off, they must cool prior to re-firing. In the printing process, during curing, a high amount of heat is generated which can distort non porous substrates, resulting in registration issues. Additionally, it is possible to dry out paper / board substrates causing curl or cracking. To combat heat, the use of dichroic filters (used to remove IR energy), water cooling and air cooling have been utilized, but at best are only able to remove about 50% of the total heat load generated. Unfortunately the water cooling and air cooling needed for UV lamps, along with the exhaust needed to remove ozone, makes them bulky, limiting placement options. And UV lamps are very inefficient, typically utilising less than 15% of the energy produced. Lastly, UV bulbs degrade continuously throughout their rated life, which is typically less than 1,000 hours, meaning that UV curing strength can be a troublesome variable to deal with during the production cycle. One of the first technologies to reduce the drawbacks of UV is LED curing.

One of the earliest commercial uses of high powered UV LED was for dental work where curing with UV light of dental adhesives and fillers reduced the time the patient was held in the dental chair waiting for their work to be completed. The small compact size of a LED was able to pinpoint the area needing attention. Another early application was the use of UV LED for curing of adhesives on printed circuit boards. It was only a matter of time until the UV LED caught up with the graphic arts market to bring its advantages to the production floor.

UV LED lamps come in a variety of sizes, power and wavelengths. The output spectra of the LEDs are monochromatic. Their outputs only span, at the most, 40nm of spectrum with the peak at 365, 385 or 395 nm. (Other UV LEDs have been produced at 350, 405, 210, 250, 275 or 290 nm). Most of the special output ranges are for specialty applications such as water purification. As a rule of thumb, as the output spectra is decreased so is the maximum intensity of the lamp. [1] A 365 nm lamp at this time has a maximum output of 2 W/cm^2 whereas the 395 nm lamp has a maximum output of 10-16 W/cm^2. A traditional UV lamp has its output spectrum ranging from 190-800nm. (Figure 2) Across that spectrum, a 300 Watt/in bulb will output approx 1,650 mW/cm^2 at the surface of the print of UV light energy. In contrast, the LED lamp will output approx 500 mW/cm^2 at the surface of the print. (Data is based on lab unit testing using a standard UV lamp / 300 Watts/inch at 10 cm (4-in) from the curing stage for the traditional UV lamp and a UV LED lamp 12W/ cm^2 / 10 cm (4-in) from the curing stage – Based on measurements using a EIT UV Power Puck II. (It should be noted that the EIT UV Power Puck II used in this comparison is optically calibrated to measure traditional UVA wavelengths instead of the higher UV LED wavelengths between 385-

395nm. Therefore, in all likelihood the UV LED intensity emitted during this test may be higher than recorded here.)

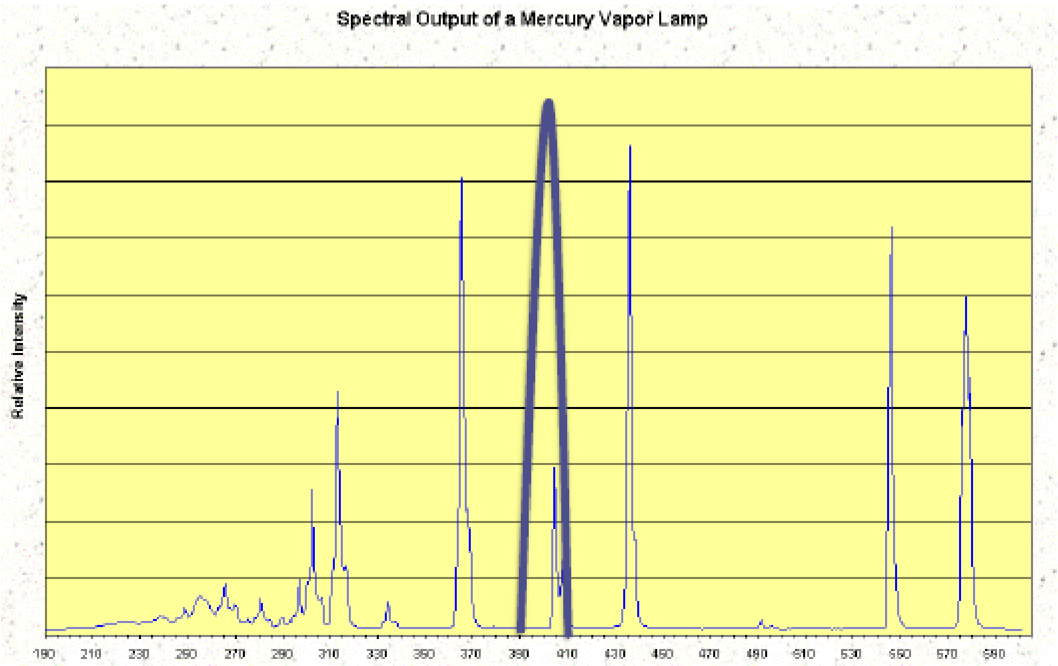

Figure 2
Medium Pressure Mercury Arc Lamp vs. UV LED (395 nm) [2]

In order to develop inks and coatings that will cure with LED lamps, the photoinitiator must utilise the energy of the lamp between the 395 to 410nm. At this time, there are very few photoinitiators which absorb within these wavelengths. This impacts the cost and efficiency of the photoinitiator package. Even though the photoinitiator absorbs in this region, the primary absorption peaks of the compounds are usually less than 395 nm and therefore the efficiency of the photoinitiator to absorb all of the available light at 395 nm is diminished. For this reason the use of LED lamps for low migration applications is not recommended.

LED lamps also have other factors which make them more desirable than traditional UV lamps: 1) Because the wavelength of the light produced by the LED is not in the area of 280 nm or less, this means that no ozone is produced by these lamps and thus, there is no need for an external exhaust. Traditional UV lamps require exhausting of the ozone. 2) LED lamps run at cooler temperatures than traditional UV lamps because narrow UV LED bandwidths eliminate the heat-producing spectral range of IR, and there are greater opportunities for UV LED lamp designers to remove back-side heat from the LED arrays. A LED lamp will at most produce 60°C of heat whereas mercury lamps can produce heat in excess of 300°C. In order to remove heat, either large amounts of chilled air or water are required. 3) The LED lamps are instant on and off owing to the nature of their semiconductor properties. Normal UV curing lamps require time to achieve working output intensity. If the lamps are turned off, then the lamps need to cool prior to re-firing. In order to get around this, lamp manufacturers have developed the use of sometimes sophisticated and often failure-prone mechanical shutters to help reduce the time between starts and stops. 4) Because of the exhaust, cooling and shutters, traditional UV lamps are bulky. LED lamps do not require the extraction of ozone. They do require water, or air cooling in order to provide cooling to the LEDs themselves which are driven at very high power densities, but due to the lower temperatures, the size is minimal. There is no need for shutters because the LED is instant on and off. Therefore the size of the LED lamps is much smaller than a mercury UV lamp. 5) The LED lamps have been found to have much greater lifespan than normal UV arc lamps and related H-UV lamps. The LED lamps have a working lifetime of >20,000 hours whereas the UV arc lamp is rated normally between 1,000 and 2,000 hours, and H-UV lamps are rated only around 700 hours. 6) LED lamps contain no mercury where a traditional UV lamp has a small amount of mercury which would have to be disposed of properly. 7) Maintenance with LED lamps is also minimal when compared to traditional UV curing lamps. A traditional UV lamp needs to be changed every 700 -1,000 hours and the reflectors need cleaning when the bulbs are replaced.

There are some drawbacks with LED lamp technology. 1) Due to the limited amount of photoinitiators available, the LED curing of varnishes and coatings becomes more challenging. The photoinitiators that are used to cure these products have a tendency to shift yellow when cured. 2) The choice of raw materials that can be used for LED is limited and therefore the price of the inks is greater than traditional UV curable inks. 3) The LED lamps, at this time, cost almost twice the amount as a traditional UV lamp of a high quality design, such as those required for sheetfed offset printing. A 40" LED lamp would be approx. $140,000 where as the arc lamp would be $70,000. However, because faster curing inks are now available for UV LED lamps, fewer LED lamps may be required for the curing process when compared to traditional UV lamp systems. As with any new technology, as the number of units sold increases, the cost will decrease. 4) The power output of LED lamps is continually improving with intensities actually higher than traditional UV lamps now available from the top end of the UV LED lamp designs, however, wavelength output is still lacking when compared to traditional UV lamps.

At this time, the following companies offer UV LED units which are being utilised on sheetfed and webfed printing presses: IST Metz – LUV LED System, Air Motion Systems – AMS Peak LED-UV™ XP Series, KBA – VariDry LED UV, Heidelberg – DryStar UV LED, Ryobi – LED-UV and Phoseon – Fire Series LED lamps.

For more information about Flint Group's product offering for LED or any other technology, please contact Peter Baird - peter.baird@flintgrp.com or email info.packaginginks@flintgrp.com.

[1] Series of Articles on the Subject of LED UV Technology (part 2). "What are the Opportunities for LED UV Technology in the Graphic Arts Industry? The basics of LED UV Technology (Part 2)."

[2] Metcalf, Steve. President and CEO Air Motion Systems. "LED Technology for UV Applications." NPIRI 2011 Technical Conference. Eaglewood Resort and Spa, Itasca, IL. OCT 2011. Presentation.