UV LED Curing in Inkjet Printing Applications

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Abstract

LEDs have many potential advantages as alternatives to traditional UV light sources for adhesive and ink curing. However, the application of LEDs for UV curing has not been as successful as expected by many researchers, despite the many attractive features LED technology provides. The high cost of UV LEDs is often cited as the primary reason for why they are not widely accepted in the industry.

Based on our understanding of LED technology, we have compared the performance of LED based light sources with traditional UV light sources and addressed the technical issues such as spectrum and light intensity needed for UV curing applications.

While much effort is still needed to successfully use LEDs in full-cure applications, recent work between EXFO and key digital print partners has shown that LEDs will improve the quality of digital printing. Print quality is controlled through an intermediate stage called 'pinning', where UV ink is partially cured on the print media. At this stage, LEDs have many advantages compared to traditional UV light sources. The improvements in print quality including enhanced image resolution, color depth and color clarity have been discussed.

Introduction

UV curing can be defined as the process in which ultraviolet (UV) light is used to initiate a curing process in UV curable material, such as UV curable inks and adhesives. Typical UV curing materials, such as acrylics or epoxies, contain photo-initiators that, when exposed to UV light, create polymer chains that change the material from a liquid to a solid. UV curing has many advantages, such as high process speed, minimum VOC, etc.

Traditionally, mercury gas discharge lamps are selected as UV sources in industrial scale curing applications. Recently, there has been an increasing number of UV LED curing systems available on the market. LEDs have many potential advantages as alternatives to traditional UV light sources for adhesive and ink curing [1]. However, the application of LEDs for large area UV curing such as printing has not been as successful as expected by many researchers, despite the many attractive features LED technology provides. The high cost of UV LEDs is often cited as the primary reason for why they are not widely accepted in the industry.

Compared to traditional UV Lamps, beside the fact that UV LEDs are still relatively expensive, more important is the compatibility with the formulations being cured.

There are a variety of wavelengths required for formulations designed/optimized for curing with UV lamps. UV lamps can irradiate a wide range of wavelengths from 250-600nm, while a typical LED curing system offers only a very narrow band peaked at 365nm or 400nm (see Figure 1) restricting a wide variety of formulations with narrow bandwidth emissions.

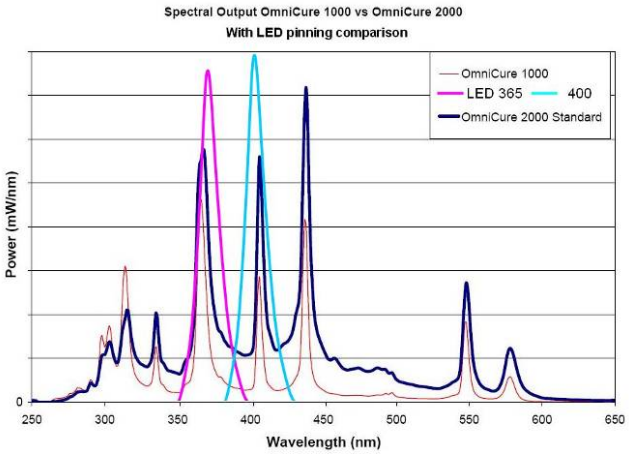


***Figure 1**. Spectral output of various UV light sources*

Although high peak irradiance (8 ~ 10W/cm^2) can be achieved through focusing of the emitted light from LEDs to a small size spot or a narrow line, to cover large area that UV lamps normally offers with reasonably high intensity is still remaining very challenging.

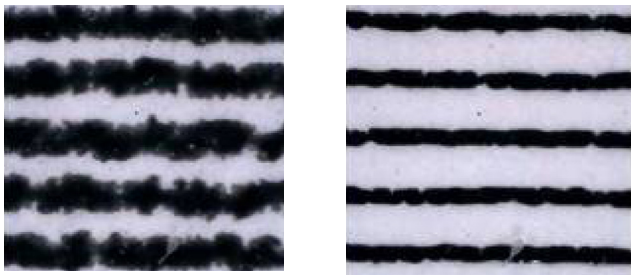
UV LED curing in inkjet printing applications

In inkjet printing applications, some attempts have been made to achieve full cure of the inks with LEDs. However, there are only little success has been reported, which is partly because of the reasons mentioned above.

Although the capability to full cure the inks with LEDs is still very limited, it has been found many UV curable inks available on the market for ink jet printing are able to be partly gelled/cured (a significant viscosity increase) after short exposure to the 365nm or 400nm LEDs. And the degree of viscosity change can be controlled by properly setting the power of the LEDs. This opens a door for using LEDs to control/improve the print quality. The LEDs have already been successfully implemented as a "pinning" tool for multi color single pass web printing [2].

In UV ink jet printing process, the viscosity of the inks is very low, after inks being jetted on print media, they usually spreads quickly. If the viscosity of the ink can be increased immediately after being jetted on the substrate, the unwanted spreading can be effectively reduced. In Figure 2, it shows the improvement in line width with a pinning UV light source in

place. Beside the control in line spread, pinning also helps to minimize the printing quality issue caused by dot gain, solids mottling, and incorrect color mixing, etc.



Without pinning With pinning

***Figure 2**. Pinning improves the line width control*

As shown in Figure 3, the LED heads is very compact and therefore it can be easily inserted between print heads. They fit well within the compact frame of the inkjet head array. Beside the compact size, using UV LED heads for pinning has many other advantages over UV lamps:

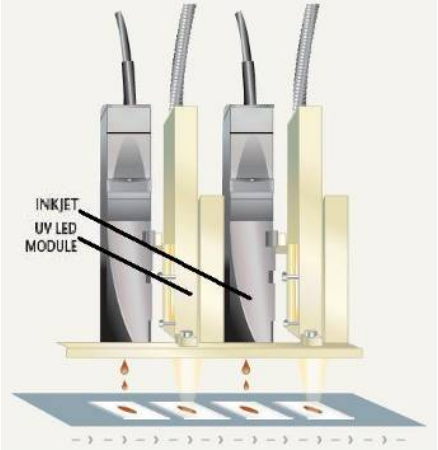


***Figure 3**. LEDs are used for pinning immediately after jetting*

1. The UV lamp may require a large cooling airflow, which could interfere with the jetting of tiny ink droplets.
2. The UV lamp creates significant heat load which may affect the printhead performance.
3. The UV lamp generates a lot of UV light, some of which could shine directly, or be reflected into the print heads, causing the ink to be cured there, then requiring the head to be serviced or replaced.
4. The UV lamp may take many seconds or even minutes to reach stable operation so must be often be left in a 'standby' mode when the web is not running which still generates heat and air flow.
5. The most frequently used UV arc lamps have typically 1000 hour life time which requires replacement at least 5 times faster than LEDs.

An extensive set of experiments was undertaken to explore the advantages of using LED pinning to improve image quality for label printing on a Digital Web Press. The mechanism of "pinning" involves retarding the fluid behavior of the ink by creating a gel through partial initiation of the cross-linking reaction in normal atmospheric air. This may be controlled to an extent by varying the intensity of the LED pinning head. Two different wavelengths were studied, 365 and 400nm.

For a successful implementation in a multi-color single pass printing system, the pinning head needs to be physically small so that it can be mounted directly next to the inkjet head to give a relatively low dose of UV light immediately after jetting. Each head should be independently varied in power level, from an instant on/off to any level in between 10 and 100%. The intensity of the pinning can then be optimized for the print results a choice of 365nm or 400nm heads have each been shown to have better matching to certain inks and colors.

Through the printing trails, it has been demonstrated that the ink, the LED wavelength and the intensity can be optimized for best effect.

Figure 4 is a real print trial result which shows the printing quality improvement with LED pinning.

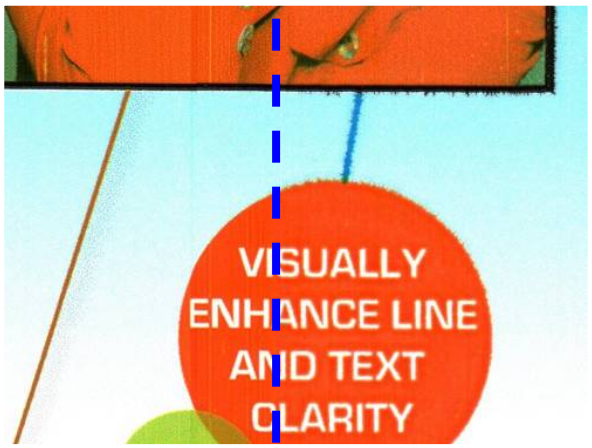


***Figure 4**. A real print trial result which shows the printing quality improvement with LED pinning: Left side was with pinning on and right side there was no pinning.*

It has been shown that pinning offers added value in terms of control of drop spread on primer-coated paper, therefore increasing the flexibility of the press, but also as a tool to control the wet-on-wet ink behavior that affect print quality on all substrates.

Pinning using LED units offers an increased degree of control over image quality in term of not only ink wetting to the substrate but also the interaction between different process colors.

Summary

While much effort is still needed to successfully use LEDs in full-cure applications, recent work between EXFO and key digital print partners has shown that LEDs will improve the quality of digital printing. Print quality is controlled through an intermediate stage called 'pinning', where UV ink is partially cured on the print media. At this stage, LEDs have many advantages compared to traditional UV light sources. LED pinning improves print quality including enhanced image resolution, color depth and color clarity.

Acknowledgment

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References

[1] K. Dake, E. Montgomery, Y. C. Koo, and M. Hubert, "LED curing vs. conventional UV-curing systems: Property comparisons of acrylates and epoxies", in RadTech Report, September/October 2004, pp. 51-55 (2004).

[2] A. Ridyard and M.Bale, "Enhancing label printing quality with UV pinning", an EXFO digital Printing White Paper in collaboration with SunChemical, (September 2007).

Author Biography

Guomao Yang received his B.Sc. in Physics from Fudan University in China (1982), M.Sc. in Solid State Physics from Tongji University in China (1987), and Ph.D. from Darmstadt University of Technology in Germany (1995). Since 2004 he has worked as a research scientist at EXFO LSI division in Mississauga, Ontario, Canada. His work has focused on the research of the response of UV curable material under various UV irradiation conditions.