UV Lamp Selection – Arc, Microwave and UV-LED

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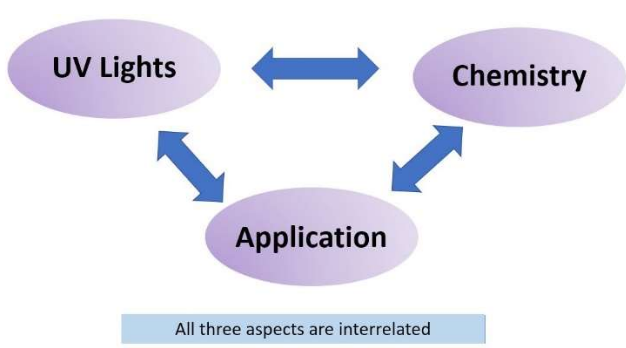
Introduction

It is difficult to escape the visual impact of brightly colored cans as you stroll through the store aisles. In addition to protecting the unique, eye catching designs that project a brand image, the high gloss UV coatings also provide a damage resistant finish. This artwork and finish are created on commercial UV sheetfed litho printing presses. The UV lamps are located after each ink station and will cure each color ink immediately after it is printed. The inking section of these presses have very little space for the UV lamp, and they can become cumbersome to maintain, they generate a lot of heat which can damage the press and can typically have short lamp and reflector life. On these presses the UV lamps are cooled by water or air. Since these presses have a tight space constraint in which to mount a lamp, it can limit which type and power of lamp that can be used to cure the ink. Therefore, microwave lamps are almost never used since they are too large. However, after the sheet is printed, there is almost always a set of lamps to complete the cure of any partially cured ink. In this area (or space), there is room so that any lamp type could be used to complete the ink cure. This paper was part of study exploring a comparison of lamp types used for inter-deck ink curing and final ink curing and varnishes. This paper focuses on the cure and performance of protective overprint varnishes when cured with different types of UV lamps (Arc, microwave, and UV-LED). In addition, this paper presents results on the effect of different UV lamp types for curing clear Rim Coats on the bottom of the shaped cans. In a broader sense, the experimental results will be applicable to a wide range of applications where there are options to choose between high powered arc lamp, microwave lamp, or UV-LED lamp systems.

UV Lights/Chemistry background

It is well known that the success of a UV curable process is highly dependent on the relationship between the UV Lights, Chemistry and the Application. All three aspects should be balanced for a successful coating or ink (Figure 1).

Figure 1



There are three major categories of UV light sources that are commonly used in industry. These are Arc, Microwave and UV-LED lamps (Figure 2).

Figure 2

In addition, UV-LED lamps can be further divided into single wavelength and multi-wavelength lamps. Each UV light source has its advantages. These are listed in Tables 1-3.

Table 1

High-Powered ARC Lamp Technology
High Peak Irradiance 7 watts/cm2
Long Lamp Life – 2,000 to 4,000 Hours
UV Output Uniformity
Ability to Use Various Spectrum Bulbs
Very Few Replacement Parts

Table 2

Microwave Lamp Technology
No Electrode = Long Life Bulbs 6,000 to 8,000 hours
Small Diameter Bulbs = Higher Intensity 6.8 watts/cm2
Ability to Use Various Broad-Spectrum Bulbs
Fast ON/OFF – No Shutters Required

Table 3

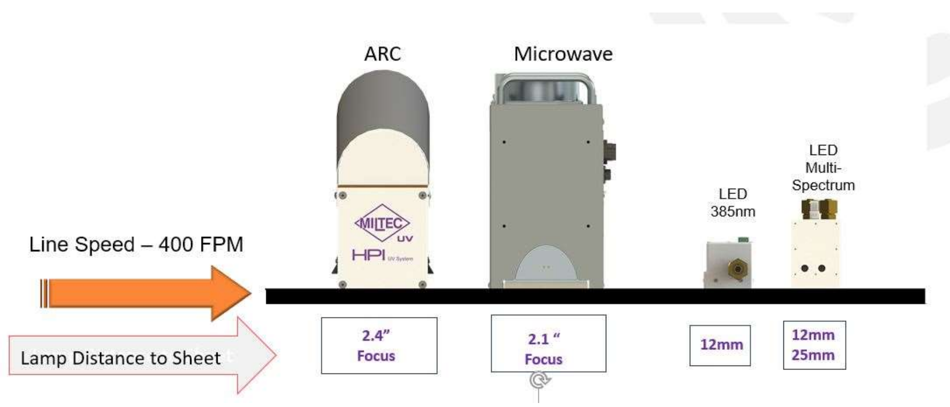
UV-LED lamp Technology
Lower Heat Generation
Instant ON/OFF – No Shutters
No Ozone Created Therefore No Exhaust System Needed
Modular Compact Design
No Mercury
Higher Energy Efficiency

To a company that is looking to either convert to a UV curable system on a can coating line or simply upgrading an older system, these advantages all look attractive. Choosing a light system often depends on the chemistry, economics, physical spacing, facilities, and of course performance.

Varnish selection must consider the existing lamps and in the best case the varnish and the lamps are selected together. There are a wide variety of varnishes formulated specifically for broadband lights such as arc or microwave. Most UV-LED systems require varnishes reformulated with a photoinitiator system sensitive to the output of the UV-LED lamps. Varnish selection becomes complicated when a plant is equipped with several different light sources and they want to limit their varnish inventory. While the experimental program that was run covered a range of different lights and formulations, this paper will focus on one aspect of the overall evaluation. Specifically, we will be looking at the use of a range of different lamps to cure Hg lamp formulated ink followed by either a Hg lamp or UV-LED formulated clear varnish.

Experimental Conditions

Figure 3

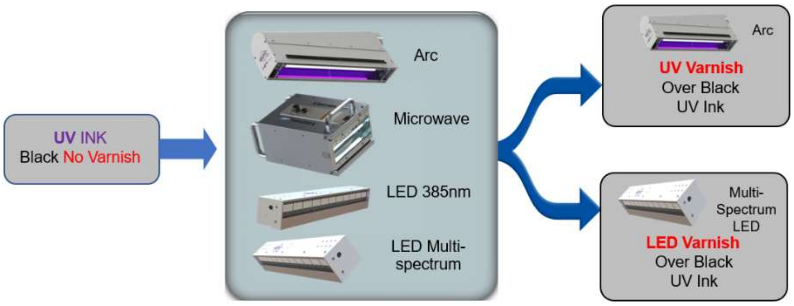


The UV lamps used in the evaluation were the Miltec UV HPI™ 23" Arc Lamp UV System, Miltec UV Xtrema Plus™ Microwave Powered UV System, Miltec UV 385nm UV-LED and a Miltec Multi-spectrum UV-LED. The Black UV curable ink was obtained from Sun Chemical. The UV broadband curable varnishes were obtained from Watson Standard while the UV-LED formulated clear varnishes were obtained from UVitec. The Ink application was done per the supplier recommendation for each ink type using either a Little Joe Proofing Press or an Orange Proofer. All clear varnishes were applied via drawdown bar. The Watson Standard 971-0452-L varnish was applied at the standard film weight of 22-26 mg/in^2. The UVitec UV-LED varnish was applied at a film weight of 22-26 mg/in^2.

Results

The experimental plan is illustrated in Figure 4.

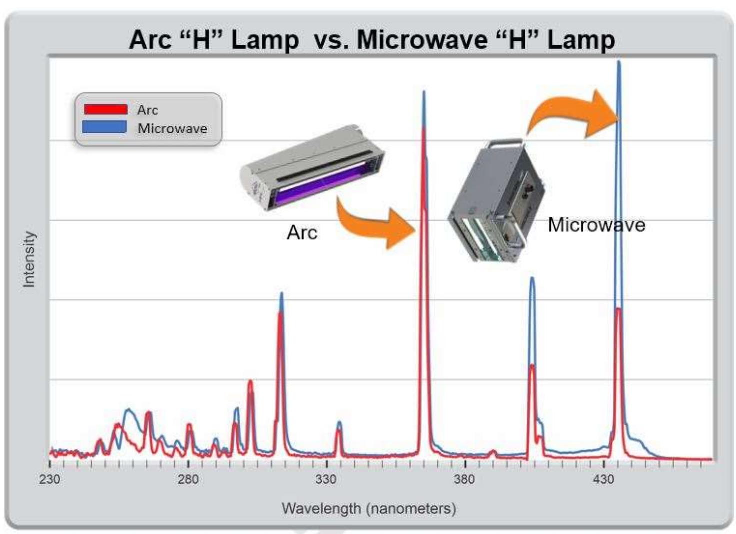
Figure 4



The UV Hg bulb formulated black ink was cured by one of the four light sources. This was then followed by coating a UV Hg bulb or a UV-LED formulated clear varnish over the ink and then curing the coated sample with either a UV Arc lamp or Multi-Spectrum UV-LED.

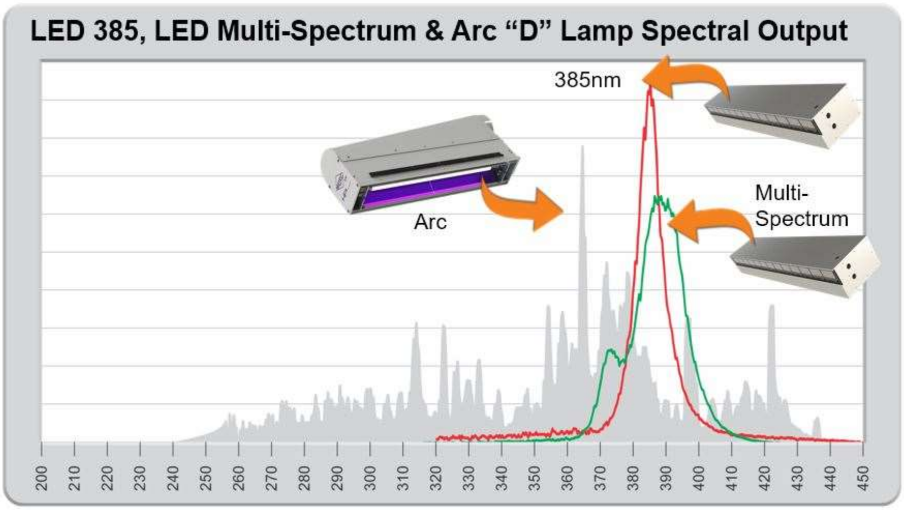
Both Arc and Microwave light sources have targeted bulbs such as H, D, etc. that are assumed to emit similar spectra. For the purposes of this study, several commonly used bulbs that are available for both systems were evaluated, and their spectra compared. Figure 3 illustrates the H bulb spectra for both an Arc and Microwave system. The individual peaks are almost an exact match. This indicates that a suitable coating formulation can be exchanged between the two lighting systems with similar results if the power output is similar between the lights. Other metal halide additive bulbs such as the "D" bulb were also examined and were shown to be similar but not identical.

Figure 5 Microwave "H" Lamp (Blue) vs. Arc "H" Lamp (Red) Spectral Output



As expected, there is a dramatic different in emitted wavelengths when an Arc D bulb is compared to either a single wavelength or multi-spectra UV-LED lamp. This is shown in Figure 6.

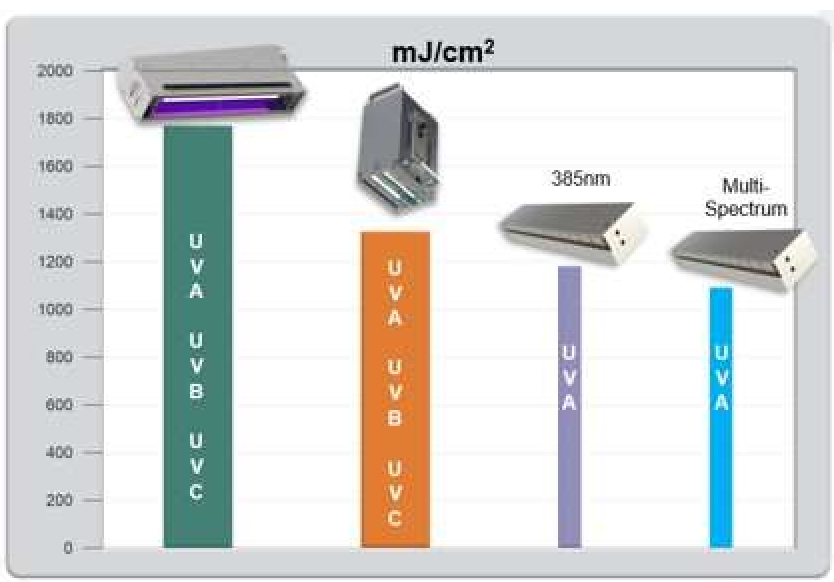
Figure 6 UV-LED 385 (Red), UV-LED Multi-Spectrum (Green) & Arc “D” Lamp (Gray) Spectral Output



However, there is enough overlap of emitted wavelengths to suggest that a Multi-Spectrum UV-LED may serve as a substitute for a D bulb.

We also evaluated the relative power output for the four different lamp systems. The results are shown in Figure 7.

Figure 7 Relative energy output (mJ/cm^2) of the 4 lamp types used in this study.



Tables 4-7 lists the results for a Hg bulb formulated or UV-LED formulated black ink and a Hg bulb formulated or UV-LED formulated clear varnish. The first column records the type of lamp used to cure the ink while the following two columns, Thumb Twist and Adhesion, demonstrate that all four types of lamps can be used to cure this ink. The remaining columns shows the results after the clear varnish has been cured using a Hg bulb formulated or a UV-LED lamp. The X in several of the tables signifies unknown results.

Table 4

UV Broadband Varnish Cured using an Arc Lamp (over UV Broadband Inks)

Black UV INK – Lamp System	Thumb Twist	Adhesion	Reverse Impact 20 in-lbs	MEK Double Rubs
Arc Lamp	Pass	Pass	0	110
Microwave	Pass	Pass	0	100
LED 385nm @ 12mm	Pass	Pass	1	110
LED 385nm @ 25mm	Pass	Pass	1	65
LED Multi-Spectrum @12mm	Pass	Pass	1	80
LED Multi-Spectrum @25mm	Pass	Pass	1	125

Table 5

UV Broadband Varnish Cured using an Arc Lamp (over UV-LED Ink)

Black LED INK – Lamp System	Thumb Twist	Adhesion	Reverse Impact 20 in-lbs	MEK Double Rubs
Arc Lamp	Pass	Pass	0	120
Microwave	Pass	Pass	1	90
LED 385nm @ 12mm	X	X	X	X
LED 385nm @ 25mm	X	X	X	X
LED Multi-Spectrum @12mm	Pass	Pass	1	70
LED Multi-Spectrum @25mm	Pass	Pass	0	80

Table 6

UV-LED Varnish Cured using UV-LED Multi-Spectrum @ 12mm (over Broadband Inks)

Black UV INK – Lamp System	Thumb Twist	Adhesion	Reverse Impact 20 in-lbs	MEK Double Rubs
Arc Lamp	Pass	Pass	0	80
Microwave	Pass	Pass	1	55
LED 385nm @ 12mm	Pass	Pass	0	70
LED 385nm @ 25mm	Pass	Pass	0	60
LED Multi-Spectrum @12mm	Pass	Pass	1	80
LED Multi-Spectrum @25mm	Pass	Pass	1	70

Table 7

UV-LED Varnish Cured using UV-LED Multi-Spectrum @ 12mm (over UV-LED Ink)

Black LED INK – Lamp System	Thumb Twist	Adhesion	Reverse Impact 20 in-lbs	MEK Double Rubs
Arc Lamp	Pass	Pass	1	85
Microwave	Pass	Pass	0	55
LED 385nm @ 12mm	X	X	X	X
LED 385nm @ 25mm	X	X	X	X
LED Multi-Spectrum @12mm	Pass	Pass	0	100
LED Multi-Spectrum @25mm	Pass	Pass	2	25

Table 8

Varnish Type	Lamp	Speed (fpm)	Lamp Height (Inch)	Thumb Twist	Tape Test	Reverse Impact	MEK Double Rubs
UV	Arc Lamp	400	2.4	pass	pass	0	130
	Microwave	400	2.1	pass	pass	0	105
	LED 385nm	150	0.5	failed	x	x	x
	LED Multi-Spectrum	100	0.5	failed	x	x	x
LED	Arc Lamp	400	2.4	pass	pass	0	90
	Microwave	400	2.1	pass	pass	0	80
	LED Multi-Spectrum	400	0.5	pass	pass	0	80
	LED 385nm	400	0.5	pass	pass	0	65

After examining the different experimental results, the UV Varnish over UV Inks (Table 4) had the best results. The traditional UV varnish performed best with the High Intensity Arc Lamp. The power of the ARC lamp cures not only the varnish but also any under cured ink underneath the varnish. In an answer to the question as to what lamp system would be best for flat sheet can coating, High Powered Arc or Multispectral UV-LED lamps work excellent for inter-deck UV-LED ink curing, when enhanced by a High-Powered ARC Lamp to cure the varnish. If available, Multi-Spectrum UV-LED performed better than 385 nm UV-LED. However, all lighting systems will work for interdeck curing.

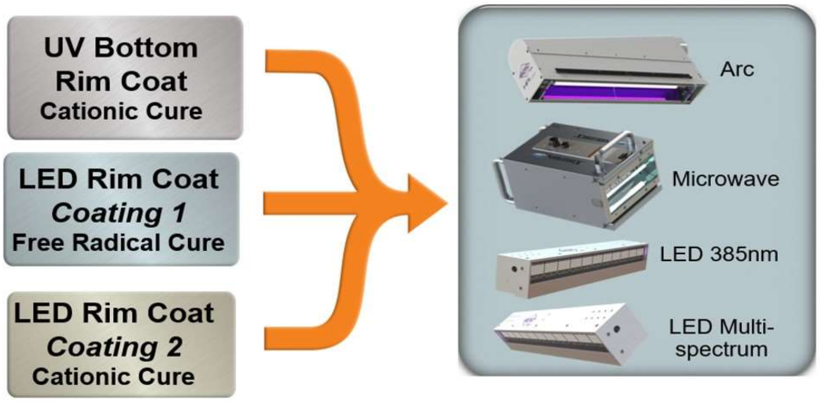
Table 8 shows all lamps can cure the UV-LED formulated varnish as production speeds. However, the UV-LED lamps were unable to cure the broadband UV varnishes at even at a third or a quarter of the production speed. This reinforces how import it is to align the photoinitiator package to the light source.

Industrial Application Bottom Rim Coat

Once a metal can is formed, the bottom rim is usually overcoated with a clear varnish. This serves to improve mobility on the production line, reduce abrasion and decreases metal dust which causes maintenance downtime. Speed is important as 230 billion beverage cans are produced globally each year and production speeds of 2000+ cans/min are common.

The process flow for this experiment is shown in Figure 8. We looked at three different UV curable formulations – a broadband formulated cationic cure, a UV-LED free radical cure and a UV-LED cationic cure formulation. Each of these were cured by one of the four different UV lamp systems used in the previous experiment.

Figure 8



The test results for the four lamp systems can be seen in Tables 9 -12.

Table 9 Rim coatings UV cured with 650 W/in2 Hg Arc Lamp in focus

Rim Coat Chemistry	Thumb Twist	MEK	Adhesion	Reverse Impact	Taber	Focal Distance	Cure Speed fpm	Pasteurization
UV Coating	Pass	75	Pass	0	0.9	2.4"	215	No Blush/ No Blisters
LED Coating 1	Pass	60	Pass	0	1.9	2.4"	215	No Blush/ No Blisters
LED Coating 2	Pass	>100	Pass	0	0.6	2.4"	215	No Blush/ No Blisters

Table 10 Rim Coatings UV cured with 600 W/in2 Hg Microwave Lamp in focus

Rim Coat Chemistry	Thumb Twist	MEK	Adhesion	Reverse Impact	Taber	Focal Distance	Cure Speed fpm	Pasteurization
UV Coating	Pass	100	Pass	0	1.1	2.1"	177	Slight blush isolated area
LED Coating 1	Pass	40	Pass	0	5.1	2.1"	150	No blush / no blisters
LED Coating 2	Pass	>100	Pass	2	.9	2.1"	177	Slight blush isolated area

Table 11 Rim Coatings UV cured with Multispectral UV-LED Lam at 12 mm from surface.

Rim Coat Chemistry	Thumb Twist	MEK	Adhesion	Reverse Impact	Taber	Lamp Distance	Cure Speed fpm	Pasteurization
UV Coating	Pass	10	pass	0	6.7	12 mm	25	No blush / no blisters
LED Coating 1	Pass	50	pass	0	5.9	12 mm	25	No blush / no blisters
LED Coating 2	Pass	60	pass	2	1.7	12 mm	25	No blush / no blisters

Table 12. Rim Coatings UV cured with Multispectral UV-LED Lamp at 12 mm from surface.

Rim Coat Chemistry	Thumb Twist	MEK	Adhesion	Reverse Impact	Taber	Lamp Distance	Cure Speed fpm	Pasteurization
UV Coating			failed					
LED Coating 1	Pass	55	pass	0	4.6	12 mm	25	No blush / no blisters
LED Coating 2	pass	15	pass	0	2.6	12 mm	25	No blush / no blisters

When using the Arc lamp, all three varnishes cured well at 215 fpm. As the UV-LED Coating 1 was formulated as a free radical system, it did not require a post bake but was still subject to post bake as this process will occur for the interior food contacting coating in a actual processing plant. The use of the microwave UV lamp gave similar results. However, there was insufficient cure at 215 fpm, so the line speed was slowed to 177 fpm for the UV broadband coating and the UV-LED coating 2. The free radical cure formulation did not fully cure at 177 fpm requiring the line to be slowed down further to 150 fpm.

In the case of using either the multispectrum UV-LED or the 385 nm UV-LED, the cure speeds were significantly slower (25 fpm). This suggests further work in needed for these systems. While the Multispectrum UV-LED coating could cure the conventional UV rim coating, the 385 was not, even at 25 fpm. As all three of the Rim Coat varnishes were commercial products, the authors did not have detailed information on the formulations.

As one of the key performance requirements for Bottom Rim Coatings is speed, based on this experiment an Arc lamp is the best choice for this application. A comparison of the line speeds obtained is highlighted in Table 12.

Table 13 Rim Coatings cured with different UV lamp types

Rim Coatings Lamp System	Conventional UV	LED Chemistry 1	LED Chemistry 2
Arc Lamp	215	215	215
Microwave	177	150	177
LED 385nm @ 12mm	<25	<25	<25
LED Multi-Spectrum @12mm	<25	25	25

The UV arc lamp outperformed the traditional microwave lamp (215 fpm versus 150-177 fpm) in this trial. The Multispectrum and 385 nm UV-LED lamps were not competitive in this application with line speeds of 25 fpm or less.

Summary

This series of experiments evaluated different combinations of UV lamps and lamp specific formulated inks and varnishes for metal can packaging. It was found that high powered Arc or Multispectral UV-LED lamps were excellent for inter-deck UV and UV-LED ink curing due to their ability to cure and their physical size. It was also shown that a high-powered ARC Lamp was the best choice to cure the varnish (which due to its higher intensity is capable of provide extra deep curing for dense ink while curing the varnish) . In the case of Bottom Rim Coatings, Arc lamps had superior performance when compared to the microwave lamps.   Even with UV-LED formulations, UV-LED lamps did not seem commercially ready for the bottom rim coating application. As expected, there needs to be proper alignment between the chemistry of the ink and varnish and the light systems.

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