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The Growing Viability of UV LED for Automotive and Transportation Applications

Abstract

This paper will explain the basics of ultraviolet (UV) curing, including peak irradiance (Watts/cm^2), energy density (Joules/cm^2), spectral wavelength (nm) and total power (Watts), as well as the fundamental differences between electrode, microwave and UV LED curing systems. It will further highlight the benefits of using UV LED technology, the trends driving its adoption into an increasing range of production technologies and, more importantly, its growing viability in automotive and transportation applications.

Introduction

The automotive and transportation industry face several design, engineering and manufacturing challenges over the coming years. Many of these involve preparing for the Corporate Average Fuel Economy (CAFE) standards requiring manufacturers to achieve a production-weighted 54.5 miles per gallon by 2025. Others have to do with better global stewardship, driving further reductions in waste and energy consumption at assembly and supplier plants. Finally, a constantly changing worker demographic and high-tech skills shortage will likely mean even more automation and process control throughout global production facilities. For each of these challenges, many new manufacturing processes will likely need to be developed.

While conventional UV curing through the use of microwave and arc lamps has been used in automotive and transportation production processes for decades, UV LED curing is relatively new and has not gained much traction. In other markets, however, UV LED technology is much more mainstream, as significant equipment and formulation advances enable the technology to quickly penetrate a growing range of applications. This is primarily driven by the fact that UV LED technology offers numerous performance, operating and environmental benefits and is considered an enabling technology that lends its use to curing inks, adhesives and coatings on a greater range of heat-sensitive materials while delivering overall process and quality control. As a result, the transformational nature of UV LED curing is something that should be explored and evaluated for its production use viability as automotive and transportation companies strive to meet various manufacturing challenges over the coming decade.

In an effort to introduce the automotive and transportation industry to the merits of UV LED curing, this paper will begin by explaining the basics of curing from an equipment perspective.

Industrial Sources of UV Curing

Industrial sources of UV energy have long included medium-pressure mercury arc and microwave-powered lamps and, more recently, light emitting diodes (LEDs). All three technologies are used to crosslink inks, coatings and adhesives in a wide range of manufacturing processes. Both arc and microwave curing technologies rely on the vaporization of mercury within a sealed quartz tube containing an inert gas mixture. The physics of mercury are such that it emits ultraviolet light when vaporized. Electrodeless lamps employ microwaves to vaporize the mercury, whereas electrode lamps harness a high-voltage arc struck between two electrodes to achieve the same result. When the mercury is vaporized into an extremely high-temperature plasma gas, it emits a spectral output across the UVA, UVB, UVC and UVV bands that can be manipulated a small degree by introducing metallic additives to the inside of the lamps. Lamps with added metals are typically referred to as doped, additive or metal halide. Most ink, adhesive and coating formulations over the past several decades have been formulated to match the output of standard mercury lamps as well as iron and gallium doped lamps. When the formulations are exposed to the ultraviolet energy, they are crosslinked into a photopolymer.

UV LEDs, on the other hand, are solid-state semiconductors. They contain no moving parts or mercury plasma gas and operate at temperatures that are often less than 1/10 the operating temperatures of conventional lamps. When connected to a DC power source, an electric current flows through the semiconductors, dropping electrons into a state of lower energy as they travel from the negative to the positive side of each discrete LED. The energy differential is released from the device in the form of a relatively monochromatic spectral distribution.

Commercially, UV LED technology has significant market adoption with longer UVA wavelengths (365, 385, 395 and 405 nm), and development work in shorter UVB and UVC bands continues. While there is no UV LED source that directly mimics a conventional lamp, the longer wavelengths emitted by LEDs result in their spectral distribution being more similar to an iron or gallium lamp than a basic mercury lamp. The result is that UV LED wavelengths can penetrate deeper into the chemistry and produce better through-cure, particularly with opaque and pigmented formulations. For clear coatings, achieving a hard, scratch-resistant surface cure without yellowing has been the primary challenge for UV LEDs. This is because many coatings formulations rely on the shorter wavelengths emitted by broadband lamps for sufficient crosslinking at the surface, and current UVB and UVC LEDs do not yet satisfy curing requirements in these shorter wavelengths. Nevertheless, higher irradiances and adjustments to the formulations often have been found to resolve these issues. For the others, ongoing development work is being done to attempt to close the gap.

Segment	Innovators	Early Adopters	Early Majority	Late Majority
Digital Inkjet	Accomplished	Accomplished	Accomplished	In Progress
Spot Curing	Accomplished	Accomplished	Accomplished	In Progress
Screen – Graphics	Accomplished	Accomplished	In Progress	
Offset - Sheet Fed	Accomplished	Accomplished	In Progress	
Flexo - Narrow Web	Accomplished	Accomplished	In Progress	
3D Manufacturing	Accomplished	Accomplished		
Structural Bonding	Accomplished	Some Installs		
Coatings – Wide Web	Exploring	Some Installs		
Flexo - Wide Web	Exploring			
Offset - Web	Exploring			
Screen – IMD	Exploring			
Coatings – 3D Parts				

FIGURE 1: *General state of UV LED adoption across a range of UV curing applications*

Both microwave and arc lamps are widely used in today's manufacturing processes, as they have been for decades. By comparison, UV LED lamps represent a much smaller but growing proportion of the installed base, with the first devices appearing on the market in the early 2000s. For many years, UV LED curing systems were of relatively low power and had limited commercial use. But – after more than 10 years of continued advancements in the areas of power output, efficiency, reliability, operation, integration, formulation and production economics – the technology is being utilized across an ever growing list of applications. The exciting evolution of UV LED technology continues, presenting numerous opportunities for manufacturing processes – including many of interest to the automotive and transportation industries.

UV Curing Market Evolution

The development efforts for industrial curing utilizing arc lamps (1940s), microwave lamps (1970s) and UV LEDs (2000s) each have their unique beginnings. Regardless of how rudimentary or seemingly inconsequential those beginnings may have appeared at the time, each formed building blocks that eventually made much more challenging feats possible. In much the same way, UV LED curing continues to evolve and prove its effectiveness in increasingly more demanding scenarios. As a result, it is reasonable to expect the use of UV LED technology in production environments to follow a similar development and adoption path over time.

The earliest commercial successes for UV LED, occurring between 2004 and 2010, were rather limited in scale and scope when measured against the much larger and significantly more established installation base of conventional UV curing. Many of the first UV LED installations involved spot-curing adhesives and digital inkjet inks. The applications predominantly dealt with slower line speeds or longer dwell times and involved installations that were conducive to the low-power emitting sources being positioned very close to the cure surface.

For those closely tracking the progress of early UV LED curing developments, it became clear rather quickly that the technology eventually would be good enough to fully capture the early adopter markets and later expand into other markets. It was just a matter of time, effort and funding, as well as establishing sufficient demand amongst end users. For those on the outside, however, it was equally easy to discount the impact that any UV LED successes in these isolated markets would have on all the other UV curing markets. To most, the fact that early UV LED sources were simply not as good at curing existing chemistry as conventional UV sources drove many overarching conclusions that the technology's impact ultimately would be restricted. It is important to note, however, that it is all too easy

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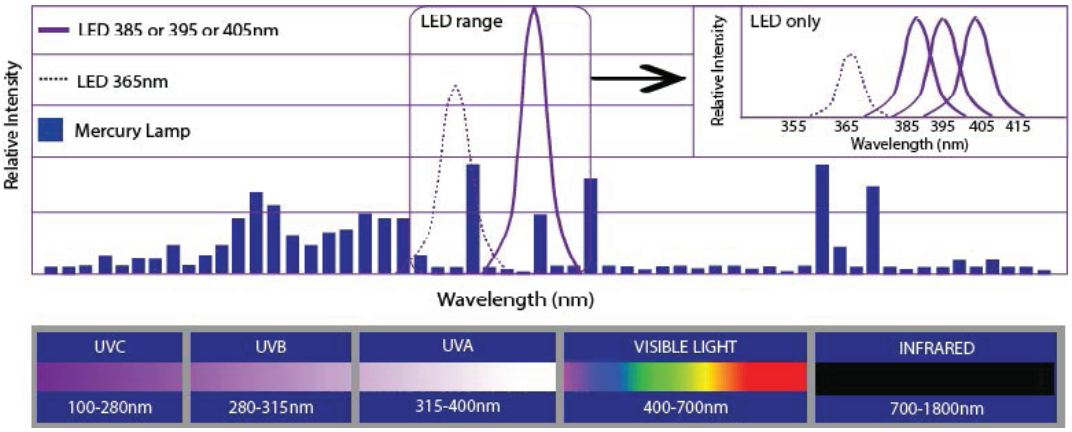

FIGURE 2: *Spectral distribution of conventional mercury lamps and UV LED lamps at 365, 385, 395, and 405 nm.*

to forget the fact that the application successes in conventional UV curing often had their own meager and challenging beginnings and have come a long way since.

Fortunately, due to the fact that UV LED sources are essentially high-tech electronics, subsequent product design iterations of the emitting source technology have followed development curves similar to those of other electronic devices, including smartphones, laptops, tablets and flat-screen televisions. As a result, between 2010 and 2017, UV LED sources became increasingly more powerful, more efficient, more reliable and less expensive. This trend is expected to continue. Formulators who committed themselves to tweaking existing UV formulations or creating new ones with chemistry optimized for the UV LED source also were able to leverage these advancements in source technology to achieve improved curing results in their formulations. As the number of successful UV LED demos, lab tests, line trials and installations has grown, more end users have subsequently become aware of UV LED technology and the benefits its use lends to their processes. Today, an even greater number of end users demand further development of the technology, and formulators and equipment suppliers are responding.

It should be noted that no two UV curing markets have evolved or will evolve at the same rate, as each market has vastly different expectations and requirements for UV power, emitting source efficiency and reliability, form factors, investment and operating costs, and chemistry. Business strategies, available resources and goals also vary drastically across markets. For those who have taken the time to assess UV curing's diverse market needs, it makes complete sense that UV LED was viable for digital inkjet printing of short-term signage, promotional business giveaways and disposable goods labels long before it would ever be viable for a durable industrial print or a functional hard coating in a demanding application within the automotive and transportation markets. The application, curing and economic needs of the two are just too drastically different to be met with the same source and formulation solution. In the automotive and transportation markets, the need for the end-use product to withstand environmental weathering and rugged wear and tear – while delivering significantly greater life expectancy, durability and quality — makes these applications more demanding. Fortunately, what once seemed impossible now is starting to appear viable and is resulting in greater interest and development for these more challenging applications. Refer to Figure 1 for a general overview of UV LED adoption as it stands today.

Characterizing Sources of UV Curing

All UV curing sources can be characterized according to spectral wavelength (nm), peak irradiance (Watts/cm^2) and energy density (Joules/cm^2). As with all spectral emissions, UV light exhibits properties of both photon particles and waves and is defined according to its wavelength. For ultraviolet wavelengths, this distance is on the order of a billionth of a meter and is typically categorized into bands of UVC (100 to 280 nm), UVB (280 to 315 nm), UVA (315 to 400 nm) and UVV (400 to 700 nm). While arc and microwave lamps are considered broadband sources in that they include wavelengths across the full UV spectrum as well as infrared, UV LEDs are relatively monochromatic and much more intense, with peak UVA wavelengths of 365, 385, 395 and 405 nm. Refer to the chart in Figure 2.

It should be noted that significant research and development in the UVC and UVB bands is being driven by the medical (UVB) and purification and sterilization (UVC) industries. The latest UVC and UVB LEDs are currently very low power (<250 mW/cm^2), relatively inefficient, offer very short lifetimes (<1,000 hours) and cost hundreds of times more than UVA diodes. Current UVC LEDs are about 1/50 the efficiency of UVA LEDs, and UVB LEDs are about 1/25 the efficiency of UVA. In general, UVC and UVB LEDs are thought to be several years or more away from practical commercialization at much lower irradiance levels and shorter lifetimes than UVA LEDs currently emit.

Peak irradiance (Watts/cm^2) is the radiant power arriving at a surface per unit area, whereas energy density (Joules/cm^2) is the radiant energy arriving at a surface per unit area. In other words, for a given surface area, peak irradiance is the delivered power, and energy density is the total delivered energy. Peak irradiance is affected by the power of the light source, the use of reflectors or optics and the distance of the source from the cure surface. Energy density is a factor of the power of the light source, the

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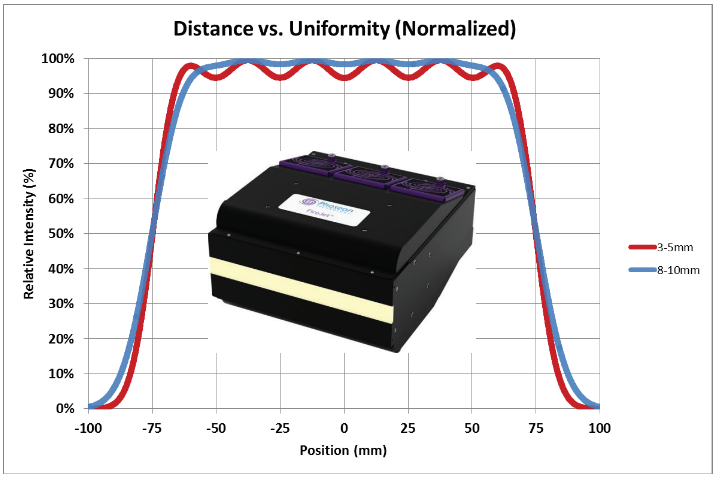

FIGURE 3: *Illustration of Uniformity of Peak Irradiance along the Length of a UV LED Source.*

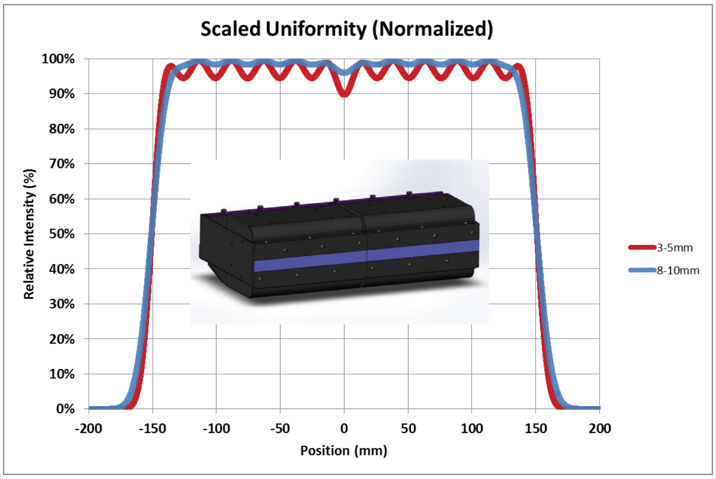

FIGURE 4: *Illustration of Uniformity of Peak Irradiance Along Length of Two Scaled UV LED Sources.*

number of UV sources and the exposure time. Understanding and managing spectral output, irradiance and energy density is essential for formulating UV curable materials, selecting the correct UV sources for a production line and ensuring the desired production speeds and cure results are achieved.

Conventional arc lamps typically emit in the range of 1 to 3 Watts/cm^2 while microwave lamps generally emit as much as 5 Watts/cm^2. UV LED curing systems, on the other hand, emit up to 16 Watts/cm^2 for air-cooled heads and 24 Watts/cm^2 for liquid-cooled heads. While the irradiance of UV LED systems is significantly greater than that of arc and microwave systems, the tradeoff is that the output is currently restricted to longer UVA wavelengths. It is important to note that, while energy density increases with increases in irradiance for a given UV LED source, a high irradiance specified by a manufacturer does not necessarily guarantee a high energy density. Energy density depends on the construction and configuration of the UV LED curing system. While a minimum threshold irradiance is necessary for chemistry cross-linking to occur, a higher energy density at or above the required minimum irradiance threshold is what delivers sufficient cure at faster production speeds. When evaluating different models from the same supplier or systems from different suppliers, it is important to understand both the irradiance and the energy density and how the two affect cure and line speed.

The fourth characteristic of UV LED sources is total power (Watts). Total power is measured by an integrating sphere and is considered to be the most accurate method of measuring UV LED sources within a given family of products and across generations of a given product. The process involves directing UV emissions from the lamp head such that they illuminate the internal surface of a large sphere coated with a highly uniform, diffuse, white material. The output of the UV LED source is reflected multiple times off the inside surface of the sphere and distributed equally to all points, allowing a small sensor to accurately measure total power independent of the source light direction. Integrating spheres are reliable, repeatable and precise tools used to evaluate the output of a UV LED curing lamp; however, the measurements from the devices are not practical for use in the field and currently are not used to determine irradiance and energy density. Irradiance and energy density are instead measured with radiometers.

UV LED Uniformity and Output Profiles

When building a UV LED curing system, numerous raw or native LEDs are typically arranged in a single line or matrix configuration. The UV output from each discrete LED follows Lambertian characteristics in that the perceived brightness remains constant as the viewing angle changes. The output from each LED is divergent and, if the matrix of LEDs is configured correctly, blends uniformly with the output of neighboring LEDs. The uniformity of the UV rays on a given plane always improves as the distance of the plane from the matrix increases.

For most applications, it is critical to have uniformity of output along the length of the LED curing source as well as between mating sources. When individual UV LED sources are seamlessly mated end-to-end, this is referred to as scaling the heads. It should be noted that not all commercially available systems are scalable, nor do they all offer the same uniformity characteristics. It is recommended that uniformity for a given product be discussed with the UV LED supplier. Sources that exhibit better uniformity along the length of the head, as well as between scaled heads, deliver better quality and consistency of cure across wider substrates or parts. In all cases, uniformity improves as the distance between the matrix and the substrate or part increases.

Uniformity of UV LED heads and scaled heads is illustrated in Figures 3 and 4. Irradiance readings were taken along the length of a 150-mm head and along the length of two scaled heads. The red trend line measurements were taken with the radiometer at a

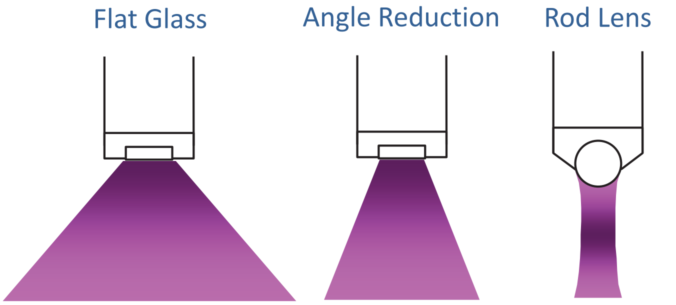

FIGURE 5: *Illustration of the Use of Simple Optics.*

distance of 3 to 5 mm from the emitting source. The blue trend line measurements were taken at a distance of 8 to 10 mm. The peaks and valleys present in the red trend line are smoother than those in the blue trend line. This is due to the matrix configuration of diodes and the Lambertian emitting nature of the LEDs.

Most UV LED sources are equipped with a protective flat glass emitting window that is placed in front of the LEDs and is generally fabricated from quartz. This is meant to serve as both a physical impact barrier as well as a means of keeping dust and other foreign matter from depositing on the LEDs and creating localized hot spots. Hot spots impact the device's efficiency and useful life. Raw diodes and their corresponding solder joints are brittle and should not be directly handled without proper training or outside of a cleanroom. Properly designed UV LED assemblies are engineered to protect the diodes. As a result, the full lamp assemblies can be easily handled but generally should not be taken apart in the field. Doing so typically voids the warranties.

UV LED source designs sometimes incorporate reflectors and optics to produce narrow, collimated or directional output. The goal of these features is to cut down on stray UV reflection and/or maintain higher peak irradiance over a greater distance. It should be noted that the use of reflectors or rod lens optics produce systems that often deliver less total energy density when compared to flat glass sources. This is due to the physical limitations in the width of the matrix when incorporating the use of optics and reflectors, as well as losses from transmission and reflection. Refer to Figure 5 for examples of simple optics.

It is generally recommended that flat glass UV LED sources be mounted such that the emitting window is between 3 and 15 mm from the substrate. For applications that do not require a relatively high irradiance, sources are sometimes mounted up to 75 to 100 mm from the substrate. The optimal distance for a given application is specific to formulation and process. It should be noted that, while irradiance decreases significantly as the distance between the UV LED source and the substrate increases, the corresponding energy density remains constant.

UV LED Thermal Management

Thermal management of UV LED curing sources is critical in maintaining proper irradiance and uniformity as well as ensuring a long lifetime. The thermal component in UV LED systems is not the radiated infrared energy typical with conventional curing sources. Instead, it is energy created by the electrical inefficiencies that are present in any solid-state electronic device. While significantly greater in magnitude for UV LED curing sources, the nature of this thermal heat is similar to that produced during operation of cellphones, laptops and chargers, as well as other high-tech electronics.

With UV LED curing, approximately 30 to 40 percent of the input power is converted to useable UV output, while 60 to 70 percent is converted to unwanted heat, as illustrated in Figure 6. If this unwanted energy is not removed, the LEDs will overheat and fail catastrophically. As a result, it is necessary to engineer an optimal cooling system that is balanced against the power of the device. This is a key factor that differentiates the products offered by UV LED source suppliers. Products that do not properly manage thermal heat within the device will experience shorter lifetimes, a reduction in peak irradiance and losses in uniformity. Furthermore, if a thermal trip is incorporated into a poorly cooled product, the device will generally turn off once it reaches the product's thermal trip point. It is recommended that users work with the lamp supplier to ensure that the delivered performance matches that stipulated in product documentation. Well-engineered products should not thermally trip when run within proper operating conditions.

In general, a UV LED curing system is an electrical device with strict requirements on maximum LED junction temperatures. Either forced air or circulated liquid coolant can be used to remove the unwanted electrical heat and maintain the desired operating temperature, thereby optimizing the efficiency of the LEDs and prolonging their useful life. Higher-powered systems are generally cooled with liquid as opposed to air, as it is more efficient. The peak irradiance of air-cooled systems, however, has increased in recent years and currently lags only slightly behind that of liquid-cooled systems. The only trade-off is that air-cooled sources are often physically larger than liquid-cooled sources since they typically incorporate cooling fans mounted internal to the lamp head. The decision of whether to use an air-cooled or liquid-cooled source is really a personal choice. If engineered correctly, both cooling methods result in a properly functioning UV LED head with no difference in output (irradiance and energy density), provided the LED matrix configuration and native diodes are the same. For more demanding applications that require more total power (Watts), a liquid-cooled solution often is the only option.

UV LED Curing Benefits

UV LED curing systems are digitally controlled, instant on/off, solid-state devices that offer superior performance and operating benefits when compared to conventional curing systems. Aside from the fact that a UV LED curing system emits ultraviolet

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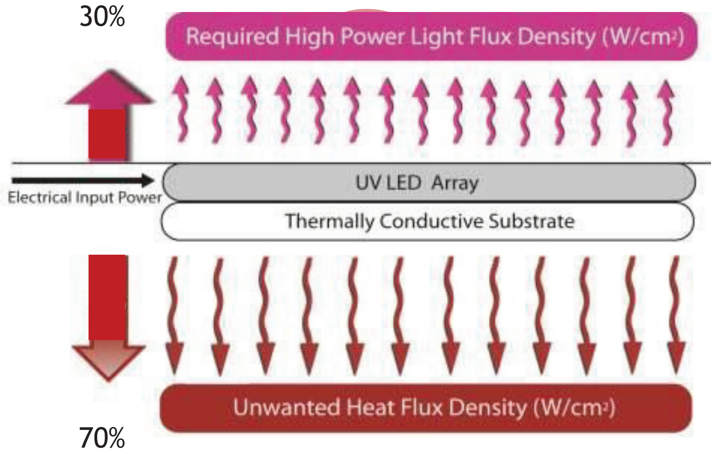

FIGURE 6: *Simple illustration of thermal heat management within a UV LED source.*

energy, the device has more in common with a typical smartphone than it does with an arc or microwave curing system. Because UV LED systems emit longer UVA wavelengths and no UVC or UVB, LED systems are better at penetrating more heavily pigmented and opaque formulations. The lack of UVB and UVC means that no ozone is produced during operation. This eliminates the need for exhaust and conditioned plant make-up air. No infrared energy also means that UV LED curing systems work across a greater range of heat-sensitive substrates. It should be noted, however, that UV LED devices still represent a source of emitted energy (Watts), even if there is no infrared component. This energy can be converted to thermal heat on the substrate or part, albeit significantly less than that generated by conventional UV sources. Parking a UV LED head over a substrate or part for a prolonged period will heat the exposed materials. The exposed part or substrate temperature, as well as the time duration needed to cause damage to the part or substrate, varies depending on the material and the setup. The beauty of LEDs is that they are instant on/off. As a result, the UV source is cycled on/off as needed and interlocked to material-handling equipment so that if any production stops occur, the light immediately switches off and then back on as soon as the line starts again.

UV LED curing systems eliminate the spare parts and accessories typically associated with conventional curing systems. These include bulbs, reflectors, shutters, magnetrons, RF screens and exhaust ducting. Conventional bulbs typically last between 500 and 2,000 hours and begin degrading from the first second they are powered. Properly engineered UV LED systems, on the other hand, have demonstrated lifetimes between 20,000 and 60,000 hours with degradation of less than 15 to 20 percent of peak output over that period. Well engineered internal device monitoring often can make adjustments to the drive power as the lamps age, thereby compensating for any natural degradation. UV LED curing systems operate on DC power, as opposed to an AC transformer or ballast, and generally consume 50 to 75 percent less energy when compared one to one with conventional systems. UV LED curing systems also eliminate mercury and ozone, as well as UVB and UVC wavelengths, all of which make for a safer operating environment. The only maintenance issues to note are keeping the emitting window, optics, reflectors and air filters clean, as well as maintaining the fill levels in the reservoirs of chillers used with liquid-cooled systems.

UV LED curing systems offer better performance and quality control than conventional sources. UV LEDs eliminate the constantly degrading, short-life quartz bulbs that produce a broadband spectral output that is essentially non-alterable due to the physics of vaporized mercury. Instead, UV LEDs produce a consistent spectral output with a nearly infinite adjustment in peak irradiance that can be scaled up and down with production needs. Knowing that UV LED sources will produce the same output across production shifts, days, weeks, months and years eliminates the troubleshooting aspects typically associated with conventional UV curing systems. As a result, UV LED curing technology generally leads to increased throughput and reduced scrap. Refer to Figure 7.

Automotive and Transportation Applications

A number of UV LED curing applications are being considered or beginning to be used by the automotive and transportation industry. Others will likely be tackled in the coming years, and new ones also will materialize. Some of the biggest advantages of using UV LED involve the reduction in heat transfer to the parts and substrates when curing inks, coatings and adhesives. This is particularly important as the industry shifts to more diverse plastic materials, lighter metallic alloys and carbon fibers to reduce vehicle weight. Dissimilar and often heat-sensitive materials that cannot be welded often are bonded though the use of structural adhesives, many of which can be formulated to cure with UV LEDs. As manufacturers continue to reduce the carbon footprint by reducing waste and energy consumption, eliminating thermal ovens and reducing overall scrap are high priorities. UV LED curing systems not only draw less power than conventional UV systems and thermal ovens, they also eliminate the need for exhaust, require less floor space and require no consumables. In addition, because the output of UV LED technology is consistent and repeatable over time, the end result is better process control and reduced scrap. Finally, like all UV curing technologies, UV formulations contain no solvent or water-based carrier that must be flashed off. The inks, coatings and adhesives quickly crosslink to form a polymeric material that is fully cured when removed from the UV lamp.

Most of the UV LED formulation work over the past 10 years have been in the areas of inks, adhesives and over-protective varnishes (OPV). Many coatings companies are now starting to evaluate UV LED curing systems for use in curing b-stage (gel), functional and hard-coat chemistry. The fact that dedicated attention now is being given to UV LED coating formulations

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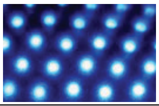
BENEFIT		FEATURE
Advanced Capabilities		Heat-sensitive, thin substrates. Deep, through curing. Controlled curing irradiance.
Operating Economics		Faster speeds. Energy efficient. Long lifetime & low maintenance. Low operating temperatures. Lower total cost of ownership.
Environmental Advantages		Mercury & ozone free. Safer UV-A wavelength. Near-ambient housing temp. Workplace safety.
Ease of Use & Integration		Solid-state. Instant ON/OFF curing. No warm-up/cool-down cycles. No shutters or exhaust ducting.

FIGURE 7: *Typical benefits and features of UV LED curing sources.*

suggests that the latest improvements in the technology are making it more viable for use in more demanding applications. In addition, the success that UV equipment suppliers have achieved in designing and producing powerful and efficient UV LED curing systems in short head lengths (<700 mm) now is being transferred to the design and production of mid and wide curing lengths (700 to 3,600 mm). Today, companies are producing both continuous-length longer heads as well as scalable heads that can be configured to span any range of curing widths or be arranged in various orientations around a part flow path. Since many commercial UV LED applications still require the UV LED head to be positioned relatively close to the cure surface to maximize peak irradiance while also maintaining a high energy density, work will need to continue over the coming years. It will be necessary to optimize both the source design and the chemistry for properly exposing and curing the complicated 3D part profiles that are so common in the automotive and transportation industry.

Based on current interest and development activity, it is anticipated that commercial solutions will be developed and expanded for many applications within the automotive and transportation markets. Some of these applications include, but are not limited to, UV LED curing of the following:

- Screen printed in-mold decorating substrates for interior vehicle assemblies
- Structural bonding adhesives for similar and dissimilar materials
- Light optically cured adhesives (LOCA) for electronic assemblies, such as radio and navigation consoles
- Conformal coatings
- Sealants, encapsulants and potting of assemblies and wire harnesses and cables
- Printed appliques
- Photoresist masks
- Printed unique IDs, logos and markings on glass
- Touch-up materials used in automotive refinish

More challenging applications include, but are not limited to, UV LED curing of:

- Hard coats for in-mold decorating substrates for interior vehicle assemblies
- Coatings for mirrors, headlights, taillights, reflectors and lenses
- Physical Vapor Deposition (PVD) on plastic parts

There are many successful ink, adhesive and coating applications utilizing UV LED curing today. While most of these applications are in printing and structural bonding, interest is growing in UV LED for automotive and transportation. Today, the bulleted list of applications predominantly uses conventional curing systems, but businesses are starting to invest time and resources into developing UV LED solutions for their respective automotive and transportation customers. Many of these ultimately will be for new applications not previously done with UV. All of this development is primarily being driven by end users and their need for less heat transfer to the substrate, a smaller carbon footprint, lower overall operating cost, reductions in scrap and improvements in process control. While it is likely that various automotive and transportation applications may not yet be viable for LED, several end users and formulators are successfully pursuing development in a growing number of areas. In addition, UV applications that were not possible with conventional arc or microwave systems – due to the large degree of heat transfer – are becoming possible with LED, thus expanding the total UV curing market.

Over the next few years, the UV industry will continue to plug away within the technology development network, one application and one market at a time, learning more and more as it anticipates the next big UV LED application breakthrough. Much of this work will actually be driven by end users who see the value in converting to UV LED technology. As a result, automotive and transportation companies should start by benchmarking where UV LED technology is today, where it is headed and how it could possibly address various process needs. It also would be beneficial to increase direct collaboration with UV LED equipment suppliers and formulators to influence where UV LED development efforts are being focused. Only by working together can we efficiently and successfully drive solutions to address the industry's manufacturing challenges of the coming decade. ◆

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