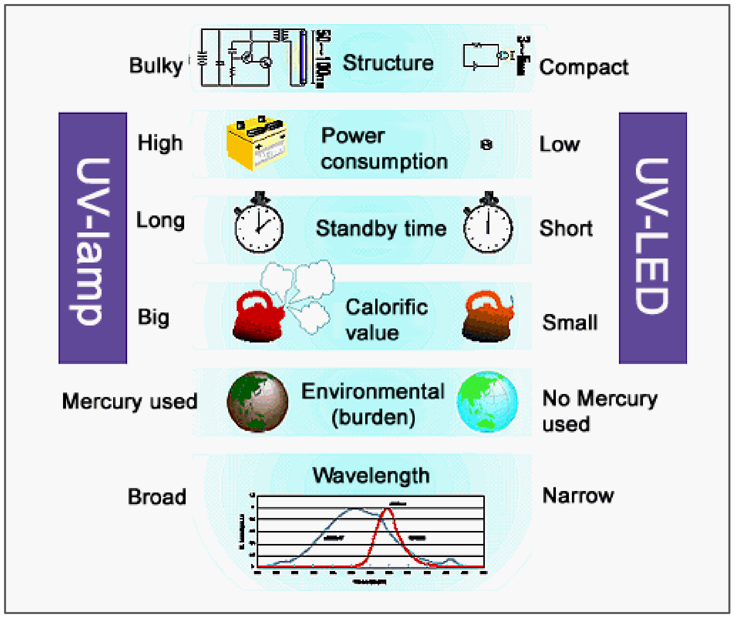
Raising the Bar on Sustainability: UV LED Light Sources

By Paul Mills, Phoseon Technology

When UV curing is discussed in terms of sustainability it's usually in the context of switching to a greener coating or more eco-friendly ink. We rightly think of the rapid speed and low energy cure of UV as an environmentally desirable alternative to more traditional chemistries.

But innovation on the equipment side is having a significant impact on the carbon footprint of UV systems as well. Commercially available UV LED curing systems that are poised to replace or complement traditional medium pressure mercury lamps provide an opportunity to dramatically reduce the energy requirements for UV cure while eliminating mercury-containing, ozone-producing arc lamps at the same time. And, the good news is that these environmental and safety benefits come at a lower cost to users.

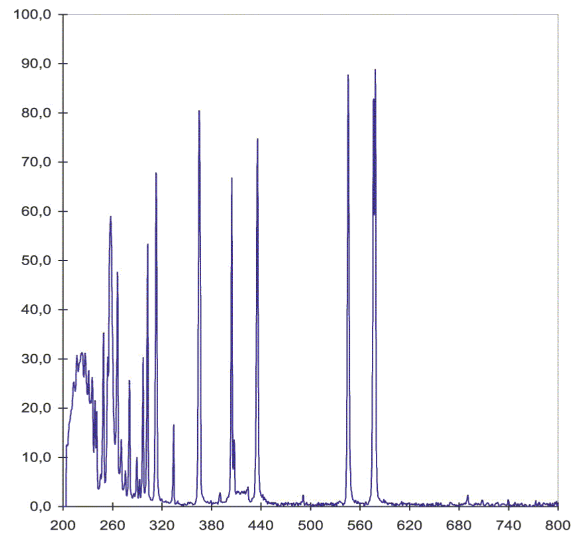


While this sort of "better-faster-cheaper" proposition should arouse skepticism, there's plenty of proof in our everyday lives to support these claims. The National Christmas tree, Rockefeller Center tree and even the ball that falls on New Years Eve in Times Square were all testament to LEDs green advantage. (USA Today reported that "consumer sales of the efficient lights have been growing for years. Fans say the lights' versatility, safety and energy efficiency could soon make incandescent bulbs a ghost of Christmas past. "

From Santa's side to stoplights, taillights and soon everyday lighting, we see LEDs making inroads at replacing conventional lighting technology.

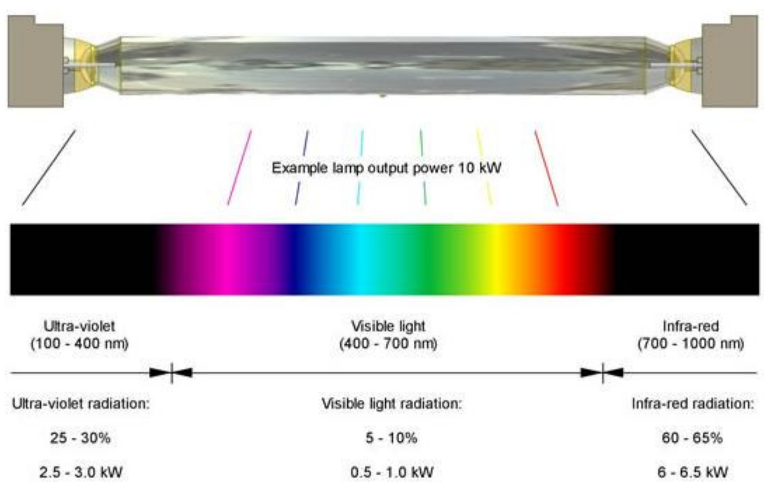
LEDs, like semi-conductor technology from RAM memory to microprocessors get more powerful and less expensive as time goes by. Even today, at this early stage of their adoption, LED sources are comparable in capital cost (on a footprint basis) with traditional UV lamps. Measured on a "cost of ownership basis" which includes their operating cost (energy and cooling requirements), longevity (an order of magnitude or more over traditional UV lamps), and maintenance they are significantly less costly.

Traditional UV sources typically produce UV by applying (a large amount of) energy to a lamp containing a small amount of elemental mercury. Excited mercury, sometimes mixed with other fill materials such as metal halides, produce the characteristic broadband output spectra of UV lamps.



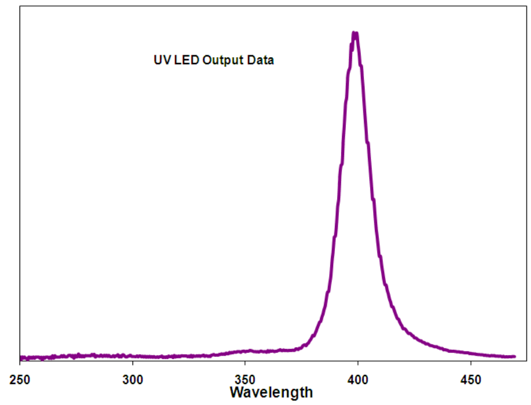
Many chemists and formulators readily acknowledge that while their raw materials, inks, coatings or adhesives cure with these broad spectra sources, that much of this spectra has no effect (or even a negative effect) on the overall process (such as the production of unwanted ozone).

The somewhat sterile spectral lines fail to illustrate in everyday terms the inefficiencies of traditional UV arc lamps. Consider instead that a conventional medium pressure UV lamp produces only 25-30% of actual UV output (not even all of which is used by the coating). 75-80% of the output is in the form of visible light and a disproportionate heat load. In fact for many UV applications such as printing on paper, thin plastic films, delicate plastics or even wood, mitigating the deleterious effects of heat are a major concern for applicators. Most conventional UV systems have significant investment in cooling. Consider that plasma can reach temperatures of 8000F within the lamp and that the glass surface is generally near 1500F. In fact if the glass is overcooled, to below 1100F there is a risk that vaporized mercury will begin to condense and the UV output will be compromised.



Contrast the output of these conventional lamps with a solid statue UV LED. The LED has a remarkably simple output. Today's sources are typically single-wavelength devices with a single peak somewhere in the 365 nm to 400 nm region.

There's no short-wavelengths to produce ozone or present UV exposure risks like eye damage or skin damage, no long wavelength heat, in fact some of these sources are not really "UV" emitters in the sense that 400 nm is a visible, purple light. So while UV LEDs pose a bright light source hazard, there are not many of the attendant operator safety concerns ordinarily associated with UV lamps.



While there are many advantages of such a "laser-like" source, especially if materials are sensitive to this peak, these selective devices also present formulation challenges.

A traditional coating designed for a broad spectral source may not cure completely or adequately with UV LED. The most common experience is that coating materials cure well with LED sources except for a thin surface layer where oxygen inhibition prevents full surface cure.

Demand For LED curing has resulted in the development of several alternatives for solving the nagging oxygen inhibition speed-bump.

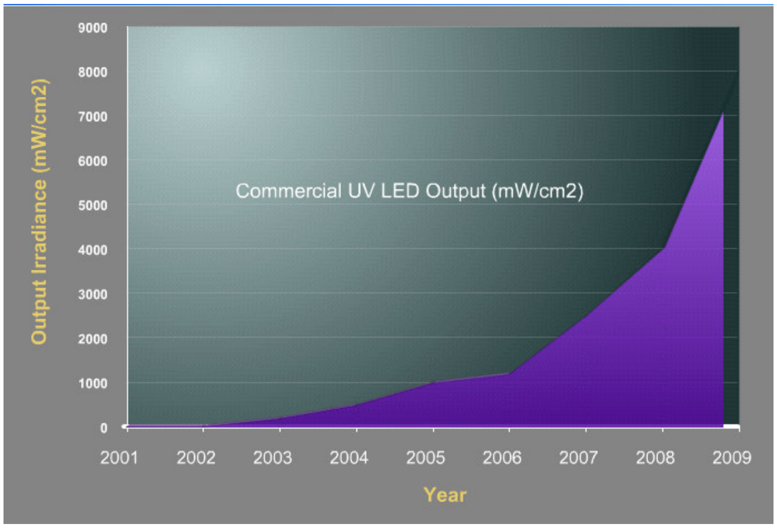
One way to prevent oxygen inhibition is to remove the oxygen itself from the UV-LED curing environment by replacing atmospheric oxygen with another gas such as CO2 or nitrogen. This "inerting" approach has been successfully used with UV LEDs for curing clear coatings on flat wood products.

Several innovative techniques make adding inerting to the process inexpensive, easy and relatively trouble-free. Since the amount of gas required is relatively small, an innovative gas generation system using a membrane separation process can be used to extract nitrogen from ordinary plant compressed air which eliminates the need and cost of using bottled gas. Phoseon Technology has developed a system to deliver the nitrogen to the cure area. This low- volume, low- flow system minimizes the amount of gas required and provides uniform distribution of the inert gas in the small space between the UV-LED source and substrate. The result is a beautiful, completely cured coating with the clarity, gloss and durability demanded for parquet flooring applications.

Another route to defeating inhibition is through increased power output of the LED source itself.

Oxygen inhibition is a race— a competition between free radicals promoting the polymerization of oligomers in the coating, and oxygen scavenging the same free radicals. Traditionally, one tool used to battle surface inhibition and increase the overall conversion rate has been to ‘use a bigger hammer.’ Since oxygen inhibition is a chemical tug-of-war between atmospheric oxygen and reactive components in the coating, more rapid photo-polymerization has traditionally been shown to have a beneficial effect.

Coatings that could not be cured with the 200 mW/cm2 sources only a few years ago now cure rapidly with sources producing over 8W/cm2 of output*. *. A parallel development in the last five years has been that these arrays have gotten larger and less expensive (an unusual but welcome occurrence in the industrial world!).



Those wishing to begin taking advantage of UV-LEDs benefits without inerting or reformulating might take a clue from the auto industry. A UV-LED/mercury lamp hybrid solution offers off-the-shelf potential.

Like the hybrid car, adding an energy-saving UV-LED array to a traditional UV- curing lamp can noticeably increase the energy efficiency, performance, and longevity of the overall system.

In recent trials, even adding a UV module prior to a single arc lamp showed significant benefits. The arc lamp, previously operating at 400W/Inch was reduced in power to 125W/Inch. A Phoseon Starfire MAX unit which produces approximately 4W/cm2 was used to provide initial curing. The arc lamp was used to provide cure to the very top surface of the coating where oxygen inhibition would normally have occurred.

In this configuration, savings in excess of 50% of the energy consumption was realized. Derating the mercury arc lamp also results in increased lifetime of the arc lamp, and better operational stability since arc lamps deteriorate faster as their output power is increased. In addition, through- cure of the coating was actually improved without sacrificing surface properties.

The slowest, but most promising avenue to the widespread adoption of UV-LED technology is the creation of new raw materials and better formulations that exploit the narrow, but highly efficient bandwidth of these devices.

As LED sources begin to proliferate in some markets, success in reformulation has already been achieved. Several digital ink formulators have already developed and are marketing inks specifically formulated for UV LED inkjet printers, and coatings formulators are working on modifications to increase performance on wood products.

Non- free-radical and hybrid- cure mechanisms are being tested, and new photoinitators that are less prone to the effects of oxygen inhibition are also being experimented with.

Customer demand and the ready availability of high-quality, high-power LED sources present the formulator with an open door to develop chemistry which responds well to these narrow bandwidth light sources.

The advantages of providing a solution that increases sustainability, while providing lower capital and operating costs are clear. The ecologic, economic, and ergonomic stars are well aligned for success.