Cork Tech Talk News

Manufacturers of Waterbase, UV+EB Curable Coatings, Varnishes and Adhesives

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UNDERSTANDING THE POWER OF ULTRAVIOLET (UV) CURING

Curing, turning liquids into solids with light, imagine that! Sounds like alchemy, and a bit of magic, but there isn't any magic involved, so let's see if we can explain away the mystery.

"UV CURING" is a photochemical process that uses a special mix of chemicals that will polymerize (cross-link) under exposure to ultraviolet light. UV curables consist of monomers, oligomers, modifying additives, photoinitiators, and sometimes pigments. The only component that is optically active is the photoinitiator. This sensitizer material absorbs UV energy, reacts to specific wavelengths of UV light, and initiates the polymerizing curing reaction. Each monomer and oligomer will cure at a different rate.

Photons, an elemental unit of light energy travel in straight lines at the speed of light. Each photons energy is a function of a distinct wavelength. Photons, like light passing through a material, can be reflected, refracted, or absorbed. When photons are absorbed their energy is turned into another form of energy, usually heat. If this energy initiates a chemical reaction, as when a photon strikes a photoinitiator molecule, a curing reaction and a photochemical process results. Ideally, the sensitizers used should absorb UV photon energy in a range that is not absorbed by monomers or pigments and the wavelength of the UV light source emission matches the wavelength absorbed by the sensitizer utilized.

A UV curing system consists of a UV source (a lamp), an irradiator/lamp housing/reflector assembly, power supply/ electrical controls, shielding, cooling and safety equipment.

The intensity of the UV radiant energy emitted by a UV lamp is called irradiance. Irradiance is measured in watts or milliwatts/square centimeter. Irradiance is a product of the power of the lamp , the lamp's diameter and the efficiency of the lamp's reflector to reflect and focus UV energy in the curing zone. Peak irradiance is the highest value of irradiance at the lamps focal point on the substrate surface.

Dose is used to take into account the time interval of UV energy exposure. One watt/square centimeter X one second = one joule/square centimeter. Dose is not an effective summary of UV energy exposure because it tells us nothing about irradiance.

UV Radiance & Dose Comparison

Lamp class	120 watt/cm	120 watt/cm
Bulb type	Mercury, electrodeless	Mercury, arc
Bulb diameter	9mm	23 mm
Cure speed	20.7 meters/min	13.4 meters/min
Peak irradiance	915 mw/sq cm	480 mw/sq cm
Dose @ cure speed	435 mJ/sq cm	620 mJ/sq cm

This table compares the curing speed of a black UV ink printed on polycarbonate through 154 thread/cm (390 thread/in) screen mesh, and cured under different lamps. Irradiance rather than dose has the key effect on curing. The smaller diameter bulb provides a higher peak irradiance and penetrates the ink film better with UV energy.

The next table compares the effects of irradiance and dose on a UV ink's depth of cure. Using the same type of lamps, the black UV ink print sees either one or two passes under the lamps of different peak power. Two passes under the lower power lamp did increase the curing depth but it did not double. This illustrates that the effects in added curing depth would diminish even farther from a third pass. Adding exposure time does not make up for the lower intensity of the lamp. Multiple passes under a lower power lamp will not give the same depth of cure as a single pass under a higher power lamp. The 120 w/cm lamps do not emit the energy needed to penetrate the ink no matter how long the ink is exposed to the lamp.

Irradiance vs. Depth of Cure

Bulb type	Passes	Peak	Cure depth
120 w/cm, D	1	3200	25.4
120 w/cm, D	2	3200	38.1
240 w/cm, D	1	6400	50.8

The table following, using a 7-10 micron black screen ink, illustrates the effect that different lamp types will have on curing speed.

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Cure speed comparison

Lamp power	**Cure speed (feet/min)**
600 w/in mercury, 28mm dia	60
400 w/in mercury, 19mm dia	70
400 w/in mercury, 13mm dia, iron	105

UV wavelengths range from 200 nanometers (nm) to 450 nm. 200 nm is the lower limit because shorter wavelengths do not transmit through air. The range of visible light is entered at approximately 450 nm. Considering the example of curing a UV ink, shorter and longer wavelengths work simultaneously to effect curing. The shorter wavelengths work on the surface, while the longer wavelengths work more deeply into the ink film. Lose the short wavelengths and the surface of the ink remains tacky. Lose the long wavelengths and ink adhesion is compromised.

Mercury is used as the principal light emission source in high intensity, medium pressure mercury vapor UV curing lamps. All lamps contain mercury, so they produce a wide range of wavelengths including short wavelengths. Therefore, all bulbs provide a degree of surface cure from the short wavelength emission. Different trace metal halide additives are used to dope some lamps. These additives increase a lamps output of particular longer wavelengths which can improve depth of cure and adhesion when used with properly matched UV materials.

Some commonly used bulbs are:

- *H bulbs: clear varnishes, coatings and inks*
- *D bulbs: some pigmented screen inks*
- *Iron (Fe) doped bulbs outputting high wattage in the 300-400 nm range are good for deep curing.*

Infrared energy in large amounts is produced by all UV bulbs. It is emitted by the quartz bulb itself and not the contained mercury or additives. Large diameter bulbs will emit more IR than smaller diameter bulbs. When heat sensitivity of substrates is an issue, a smaller diameter bulb is better. Water and air cooled dichroic reflectors that absorb IR energy are used to protect heat sensitive substrates. Water filled quartz tubes may also be used to filter IR and keep it from reaching a substrate.

The output of a lamp deteriorates slowly with use at a rate of 10 to 15% in the first 1000 hours of use. Properly handled, 2000-3000 hours of useful life can be expected. Improper cleaning and handling can shorten a lamp's useful life. Fingerprints or other contaminating marks can be etched into the quartz tube when it heats to 600-800 C. during operation. These marks are opaque to UV light and will reduce a lamps effective output. Lamps are also very sensitive to cooling and condensing of mercury thus reducing output, so no moving air should be directed at the lamp. Clean reflectors are also key to efficient UV curing.

Charts supplied by Fusion AETEK UV Systems, Inc.