PDS International Limited

Ultra Violet Curing Technology

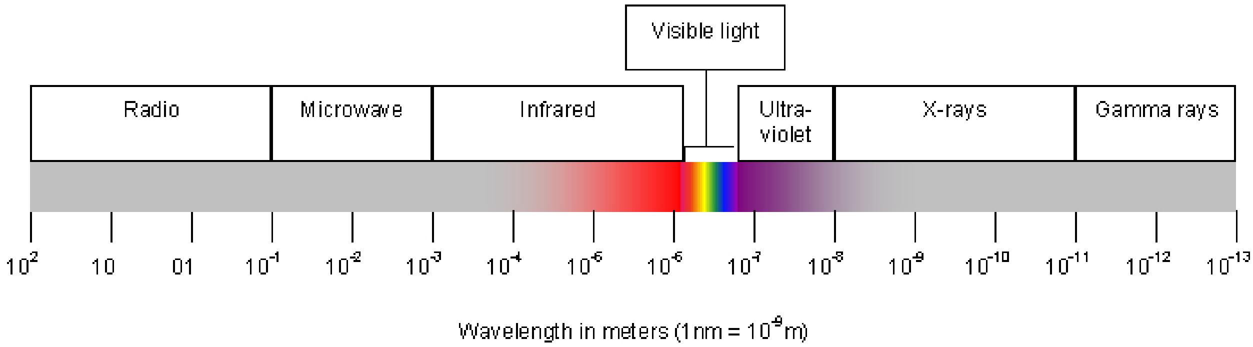
This month Peter Kiddell looks at what's new in Ultra Violet curing technology.

Ultra Violet curing resins were used with the pigments for colouring statues in Egypt at the time of building the pyramids. It makes sense, as there is an awful lot of Ultra Violet radiation in the full sun of Egypt. So, from ancient to modern.

The first thing is to indicate the differences between UV curing systems and solvent-based evaporation systems. Both systems require energy for them to cure. In the case of solvent systems it is latent heat of evaporation and air movement. With UV curing systems it is Ultra Violet light and some heat. With solvent-based systems the evaporation of the solvent leaves a dry ink film that can form a stable layer in a variety of different ways. Simple evaporation, oxidation, baking, catalytic action, sublimation, water absorption etc. There is generally a system to suit most applications.

As indicated by the reference to sun light Ultra Violet light is part of the electromagnetic spectrum very close to visible light. The diagram below shows that visible light is positioned with ultra violet at one side and infrared at the other side.

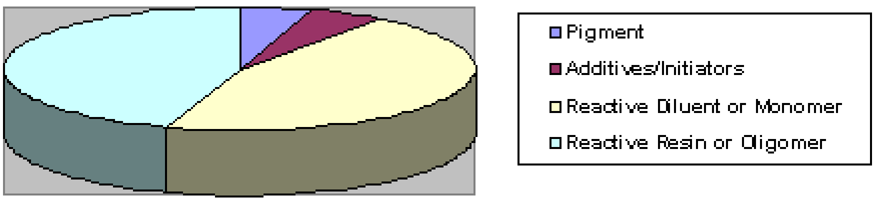
Electromagnetic Spectrum



Ultra violet radiation is actinic, it causes a chemical reaction to occur, and this enables UV inks to cure.

Conventional UV curing inks

The main components of typical UV ink are shown below.



Advantages	**Disadvantages**
Easy to use.	Build/deposit. Excessive deposit will inhibit curing. Can cause skipping between colours.
Health & Safety. No VOC's in the workplace.	Adhesion range not as wide as solvent based. Mechanical bond only
Environmental considerations. No VOC's.	Often less opaque.
Fast curing.	Not as flexible as equivalent solvent based.
High gloss - Matte range of finishes.	Colour stability inferior to solvent based systems.
Scuff/block resistant.	Relatively expensive.
Unlimited screen stability.	Ozone produced.
Good adhesion range.	Increased potential for skin sensitivity.
Space saving.	

I know there could be Epoxy acrylate prepolymers and initiators such as 2-chlorothioxanone and Benzophenone but that is of no interest to 99.9% of us. The intention here is to review the ink from the user's point of view.

There are no solvents, nothing to evaporate, ink that is stable on the screen and will normally never dry out unless exposed to high levels of Ultra Violet energy. The printers dream ink.

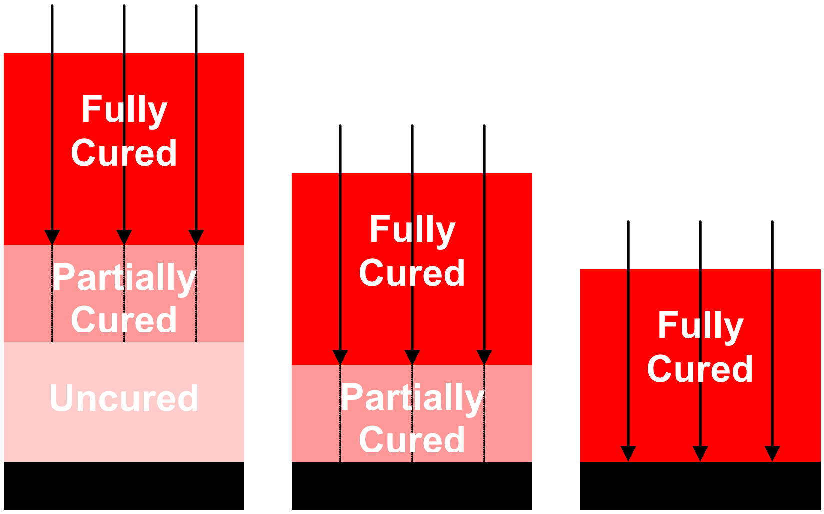
The mixture is of reactive resins, additives, pigments and photoinitiators. The only major component in common with solvent-based ink is the pigment and even these often differ from solvent-based systems. This adds up to a unique ink system.

The photoiniators are the chemicals that provide the system with its distinctive characteristics. As the name suggests *Photo* light, *initiate* start. Photoinitiators use UV light to start the chemical reaction that turns the liquid ink into a solid ink film. UV light is absorbed by photoinitiators and "Free radicals" are created. These connect with the molecules of the monomers and oligomers and they in turn cross-link with each other forming chains of molecules that is the solid ink. This is also called photopolymerisation. The addition of heat to the process will speed it up. For the chemical reaction to start the UV light must be able to impinge onto the photoinitiators. The wavelength of UV light that hits the photoiniators must be compatible with the photoiniators. After this initial reaction the ink continues to cure. Depending on the formulation and temperature a complete cure can take up to 24 hours. The resulting film is a thermoset plastic that is very durable.

Wonderful, an almost instantaneously drying ink that remains stable on the screen indefinitely, why use anything else? You must understand the limitations of the system to get full use from it.

For a complete cure to occur sufficient amounts of photoiniators must be triggered by the UV light to cause the full polymerisation to occur. If the pigment loading is very dense or the film thickness is too great the cure will be incomplete. Three factors effect the density of pigmentation one is the amount of pigment another is its colour and thirdly its opacity.

EFFECT OF INK FILM THICKNESS:



The uncured ink will remain wet and the ink will wipe off. When the partially cured ink is in contact with the substrate it will scratch or crack off. When fully cured good adhesion will be achieved.

This means that you need to apply thin films of ink, which requires higher mesh counts. 120 t.p.cm is a minimum for transparent colour rising up to as high as 185 t.p.cm for high line ruling four-colour work. 150/34 is the mesh count recommended by most ink suppliers.

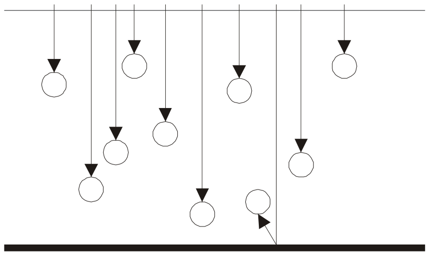
OPACITY OF PIGMENT

Highly pigmented ink of almost any colour will block some of the UV energy. Curing is fastest with clear lacquer. Followed by transparent colour as in the four-colour set.

Metallic pigments can block UV light completely. Although improving it is still very difficult to achieve the effects possible with solvent-based systems. Glitter inks are available where the individual particles of pigment are large and widely dispersed throughout the film. Although promising the effects claimed are difficult to achieve. UV curing conductive inks are used but their resistance is much greater than solvent equivalents. In every case the UV light must be able to get to the photoinitiators to trigger the reaction.

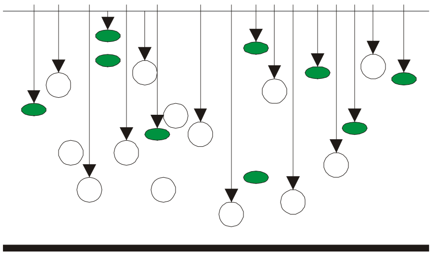
EFFECT OF COLOUR ON CURING

Green UV ink is the most difficult to cure other than dense whites and blacks. Green is natures' colour for absorbing UV energy. Grass and leaves. Plants need to capture UV light to carry out photosynthesis. In autumn leaves turn brown or even red to allow the UV to pass straight through. Light green ink on a dark green background needs a lot of energy to cure. The light green blocks and the dark green absorbs the UV light. From this you can see that the curing of UV ink can be effected by both ink and background colour.



Photinitiator

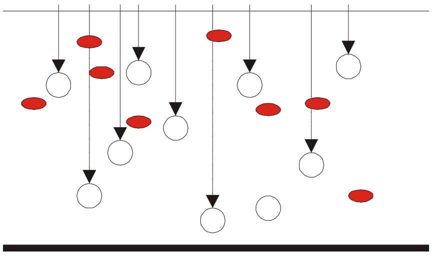
Clear Varnish (Very Fast)



Pigment

SLOW

Green Ink (Slow)



Pigment

FAST

Red Ink (Fast)

To increase the amount of UV energy you either have to increase the lamp output or slow the conveyor. Both of these will tend to boost the amount of heat applied to the substrate, which can alter the size of the sheet thus affecting registration of subsequent colours. It is possible to cool bulbs and put quartz infrared filters in front of them but this can affect their efficiency. Done correctly it can resolve the problem. Even flash or pulsed curing causes a build up of heat unless effective extraction is provided.

LAMPS

The UV curing lamp is critical to the process. Although the overall output of the lamp is critical it is the wavelength of the output that provides the key. The combination of this, the lamp focus and the conveyor speed adds up to what is known as the 'Dose' measured in Milli-joules/sq cm. You can measure this using a UV Dosimeter or Radiometer that you pass through the drying conveyor.

A Spectral Output at the correct dose that covers the reactive range of the photoinitiators is the aim. These tend to be in the 200-to 400-nanometre bands. The graphs give the output of three lamp types. Mercury Vapour, Iron and Gallium. Mercury Vapour is the most common and the others are known as “doped”. Mercury Vapour has additions of the other metal halides to give different spectral outputs. Doped lamps are more expensive and tend to have a shorter operating life. 1000 hours for Mercury Vapour and as low as 500 hours for some doped bulbs. Doped lamps are harder to start and less stable in their operation. Also a standard mercury vapour drive system will not operate if fitted with a doped halide lamp. Output graphs show more peaks in certain areas. If inks are difficult to cure photoiniators can be chosen to coincide with these peaks giving a better cure.

Bands of Photoinitiators - Some ink manufacturers group their photoinitiators into reactivity bands these are:

UVA (315-400nm)
UVB (280-315nm)
UVC (100-280nm)

So if they ask if you are using A, B or C you will know what they are talking about.

OPERATION OF LAMPS

Lamps are powered either with electrodes or electrode less using microwaves.

With the electrodes a current is applied and an arc is formed between the two electrodes within the lamp, which emits UV energy.

Alternatively Microwaves bombard and excite the gas causing the emission of UV energy.

The microwave system creates full power in a few seconds but is restricted in length to 10 inches with power out puts of 300 and 600 watts per inch. Lamps with electrodes can be over 12 feet long and produce up to 1500 watts per inch.

The UV output of a lamp will decrease over time as the quartz envelope that contains the active gas becomes cloudy. Operation, contaminants and frequent cycling cause the quartz to devitrify. Devitrified quartz is opaque and reduces the transmission of light from the arc. The ink takes longer to cure and the 800^{o}C temperature of the quartz envelope starts to affect the substrate.

OZONE

Short wave UV light (UVC specifically 185nm) and oxygen creates ozone a highly reactive gas. Lamps can be ozone free by altering the composition of the quartz envelope. This reduces the spectral range of the lamp so is rarely used. Extracting away from an unmodified lamp usually results in the ozone reverting to oxygen very quickly in the exhaust system. Filtration and absorption systems are also available. With sensible management ozone should not be a problem.

TAKE CARE OF YOUR REACTOR

The reactor is the assembly that generates and focuses the UV. Change the lamp when specified by the manufacturer. Keep any reflectors clean. The same applies to the lamp but do not touch it with bare hands whilst you are wiping away any contamination with Isopropyl Alcohol. Contamination is particularly a problem with a combination dryer (one for UV and solvent-based systems). The resins from the solvent-based ink collect on the reactor and are not burnt off by operational temperatures. If the reflector becomes damaged replace it as this could alter the focus of the reactor.

CURING LEVEL

Having ensured that the ink is adequately cured be aware that you can over cure UV ink. This problem occurs when printing multi-colours. If a print is completely cured subsequent prints will not adhere to it. Once the cure is completed the surface energy of the cured ink is reduced so that the ink printed on top will not wet the cured ink and is known as intercoat adhesion problems. It is necessary to adjust the level of curing on each print pass such that there is a build up of curing level until the final print. Adjusting lamp output or conveyor speed can do this.

WATER BASED UV CURABLE INK

Water based UV curing inks were developed to help reduce the ink film when four colour process printing. When Conventional UV inks cure the dry film thickness does not show a significant reduction over the wet film thickness. Higher mesh counts required to give the reduced film thickness are not always practical to use. High builds can produce skipping when subsequent colours are put down resulting in colour change and moiré. Developments in capillary films can help in reducing this problem by providing a flat thin stencil that reduces the wet ink film thickness of conventional UV inks. This could have an impact on water based UV in usage as printers would prefer to use conventional UV due to its better press stability.

Water based inks have a low build which is comparable with solvent based inks. The low build is created by the evaporation of the water in the system when the ink dries. Take care in the selection of substrates; particularly lightweight paper as cockling can result if the paper is particularly absorbent. They can be used successfully on a range of plastics, but check adhesion before committing to a run. With the thin ink deposits fine line rulings are possible 150 l.p.i. and upwards.

Advantages	*Disadvantages*
All advantages of UV.	Relatively expensive.
Reduced build, comparable to solvent systems.	More care required in storage and handling.
Water thinnable and washable.	More careful substrate (paper) selection required.
Can be used to produce poster for outdoors.	Range of adhesion not as good as conventional UV.
Low levels of Dot Gain.	Less opacity than conventional UV.
	Evaporation of water whilst on the screen requires careful monitoring of ink condition.

PRINT CHARACTERISTICS

Make sure that the emulsion on the stencil is waterproof. Although there have been improvements in inhibiting the evaporation of water from the ink on the screen, water does still evaporate and can cause colour change if not managed. The simple rule is to add fresh ink regularly to during a run. If you have had ink on the screen for some time avoid putting it back into the tub of unused ink as its water content would have changed and will contaminate the bulk of the ink.

With water based UV ink it is some times necessary to wet the mesh with water before you start printing. Always have waste material available to run to ensure that the mesh clears out after the machine is stopped for any period.

Tack, (how sticky it is during printing), is higher than conventional UV ink. The effect of this is for the mesh to stay in contact with the ink and substrate longer than is ideal print quality is reduced. Ways to overcome this are to increase mesh tension, increase snap distance or peel off. Increasing snap or peel off is the easiest solution but it does result in image distortion. A higher mesh tension will pull the mesh away from the printed surface but the increase must be within the working tension of the frame. By increasing snap or peel off you are increasing tension in the mesh during its print cycle, be careful not to go too high with any of the adjustments otherwise you will damage the mesh.

OTHER CONSIDERATIONS

UV inks will start to cure in the stencil if you have high levels of ambient UV light in the print shop. You could put blinds on the windows and on roof lights, or even to have safe light shades on your fluorescent tubes that are above the stencil.
If you use UV inks that require a catalyst some suppliers will claim they last for up to 24 hours in the stencil. Our experience is that sometimes the stability can be timed in minutes especially if the machine is stopped for some reason. The catalyst is used to improve adhesion or flexibility of the ink.

Heat is sometimes used to help ink films to flow out prior to curing with UV this helps provide a higher gloss level. It can also be used to drive off the water from water-based systems before curing. This practice can drive some of the uncured monomers as well with implications for health and safety.

HEALTH AND SAFETY AND ENVIRONMENTAL ISSUES

The dramatic reduction of the use of solvents is a great advantage in the workplace and to the environment. Curing equipment can be smaller and more efficient. Although inks appear to be expensive when compared to solvent based inks, mileage is greater and there are huge savings to be made in reduced machine down time and savings in wastage.

An area of concern that is increasing in importance is the potential hazards of using UV systems. In the screen-printing industry the problems tend to be with direct contact with the inks rather than the mists that are generated in other high speed printing processes. Choice of gloves is critical your suppliers and the SPA UK Limited can provide the most up to date information.

To be sure read the material safety data sheets provided by the ink manufacturer and follow their recommendations, they know what they are talking about.

TALK TO YOUR SUPPLIERS

The problem is UV curing and UV ink technology is a massive subject. All I do is use the stuff. It is the companies that make it who really understand the technology. Don't just listen to what I have got to say talk to your ink suppliers. Highly flexible inks for in-mould decoration that belie the inherent lack of flexibility of UV systems are available. Water based technologies that hold the water in the system are being developed. The manufacturers are constantly looking at substitutes for the more nasty reactive chemicals in the formulations. The suppliers of drying/curing unit are increasing their equipment efficiencies on an ongoing basis.

A well set up machine using UV inks is a joy to work with, as long as you maintain tight process control. Oh, and by the way, variations in ambient temperatures can affect the rheology of the ink the ideal is to print in a clean environmentally controlled print shop. The dream of many and reality for a few.

Peter Kiddell is a director of PDS International Limited,
An independent training and consultancy organisation in the UK.

www.pdsinternational.com; email: peter@pdsinternational.com