White Paper

UV-curable Inks

The Future of Industrial InkJet Printing

Today, digital printing is fast becoming the preferred method for short-run and variable-data applications. While toner-based systems, such as Xerox Docucolor™ currently dominate document and variable-data printing, inkjet systems such as Agfa's :Dotrix Transcolor are gaining market share.

For wide format applications, such as tradeshow displays, billboards, signs, posters, banners and vehicle graphics, inkjet printing has always been centre stage. Inkjet is the choice for these types of printing because of the versatility of inkjet technology and the nature of inkjet inks. Inkjet inks are far more versatile. They extend beyond the CMYK colour set to include Light Magenta, Light Cyan, Grey, Photo Green and Blue, and even White. Such colours widen the gamut dramatically giving sign, display and screen printers a palette that allows them to match customised colours and reproduce vibrant, eye-catching colours.

The most popular digital inks for wide format applications are solvent-based and UV-curable inks. Solvent inks have been more popular for long-term outdoor applications. However, advanced technical developments, along with stringent R&D testing have shown that the quality characteristics of UV-curable inks now rival their solvent-based counterparts. In three important areas UV-curable inks excel over their solvent counterparts: rapid drying characteristics allow unencumbered high-speed printing, substrate versatility (direct adherence to both flexible and rigid materials) greatly widen applications and eliminate the time-consuming step of mounting a printed substrate on a hard base; and finally, having no VOCs (Volatile Organic Compounds), they offer considerable environmental benefits. The advantages of UV-curable inks, therefore, far outweigh any disadvantages, earmarking them as the dominant consumable for the future of industrial inkjet printing.

Redefining inkjet printing

As a result of the technological evolution that has taken place over the past years regarding developments in printheads, inks, software and hardware, there is a clear need to redefine inkjet printing. Up to now inkjet printing was categorised based on the print width of printers:

SOHO	**< 60 cm / < 24 in**
Wide or large format printing	**60 cm – 250 cm / 24 in – 100 in**
Superwide or grand format printing	**> 250 cm / > 100 in**

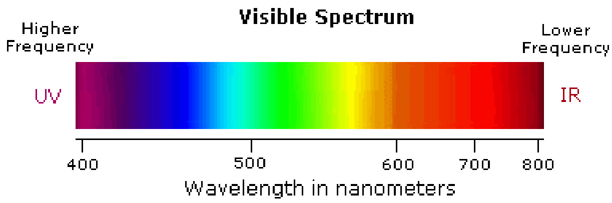
AGFA

As a result of this subdivision it is difficult to position a typical industrial inkjet technology such as single pass printing. Therefore we subdivide inkjet printers based on printing speed (m^2/hr):

	Typical printing speed	Dominant ink type(s)
SOHO	< 5 m^2/hr	aqueous
Classical wide format printing	5 – 20 m^2/hr	aqueous and solvent
Industrial wide format	20 – 100 m^2/hr	solvent and UV
Industrial inkjet	> 100 m^2/hr	UV

The UV-curing process

UV stands for ultra-violet, which refers to the wavelength of the light being used for the curing of UV-curable inks. Ultra-violet light is electro-magnetic radiation situated on the high frequency side (between 200 and 380 nm) of the light spectrum.



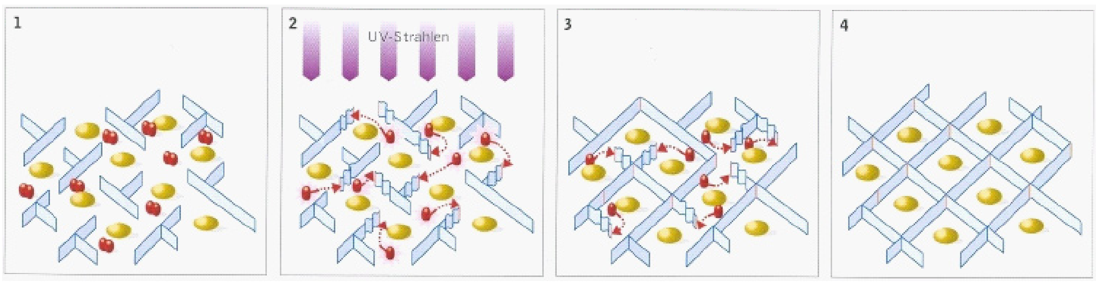


Figure: UV curing proces:

1. Schematic representation of UV ink, being jetted onto a substrate; pigment particles (yellow), photo-initiator (red) and monomers and oligomers (blue)
2. The UV light degradates the photo-initiator into free radicals which chemically react with the monomers and oligomers
3. Photopolymerisation continues until all monomers and oligomers have reacted
4. Solidified UV-curable ink with captured pigment particles

After being jetted onto a substrate, the UV-curable ink is immediately cured upon radiation with UV light. During this curing process the monomers[1] and oligomers[2] immediately polymerize[3] resulting in instantaneous solidification of the liquid ink droplet on the substrate. Since UV light does not have enough energy to start the polymerization process, photo-initiators are added to the formulation. These compounds generate free radicals[4] that are needed to start the polymerization process (solidification of the ink).

UV Curing Technology in Everyday Life

It is used to modify the properties of plastics.

It helps achieve the ideal hardness of contact lenses

It works to tune the surface properties of lacquers

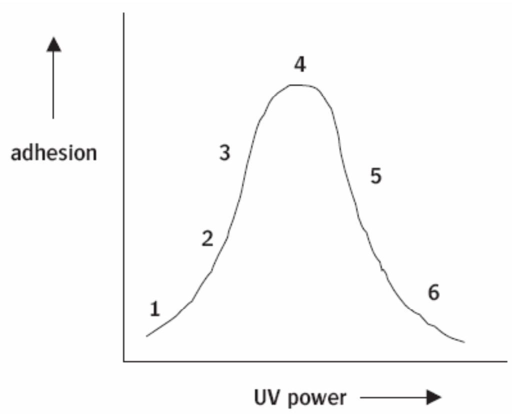
It allows very fast hardening of dental fillings

Conditions Affecting Adhesion

The UV-curing process is very complex. Many parameters, such as ink colour, thickness of the ink layer, type of substrate, UV light source, exposure time, atmosphere, etc. can all affect the photopolymerization process. UV power and ink colour illustrate this.

UV Power

1. Little or no exposure, ink remains liquid
2. Partial curing (usually surface only) with possible “skinning” results in poor adhesion to the substrate
3. Tacky surface, common to under curing
4. “Correctly cured” with no tack, low odour, flexible and with good adhesion
5. Increased surface hardness that can become brittle with poor over printability
6. Primary ink surface not receptive to secondary inks resulting in poor adhesion and low flexibility



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[1]A **monomer** is a small molecule that may become chemically bonded to other monomers to form a polymer.

[2]An **oligomer** consists of a finite number of monomer units in contrast to a polymer which consists of an unbounded number of monomers.

[3]**Polymerization** is a process of reacting monomer molecules together to form two- or three-dimensional networks of polymer chains.

[4]**Free radicals** are particles with unpaired electrons that are usually highly reactive, so radicals are likely to take part in chemical reactions such as polymerization.

Ink Colour

Black inks are more difficult to cure. That's because the black pigment particles absorb a significant amount of the UV light. Thus, more UV power is needed to obtain the same degree of adhesion. White ink has a similar effect. Instead of absorbing light, white ink reflects UV light. This also means that more curing power is needed to obtain similar adhesion characteristics.

Advantages of UV-curable inkjet inks

UV-curable inks have a number of advantages over other digital ink types.

- High printing speeds
- Applicable for a wider range of substrates
- Colour consistency
- Ecologically friendly – no VOCs (Volatile Organic Compounds)
- Less ink consumption per m^2

High printing speeds

Solvent-based printers require dryers to remove the large amounts of solvents from the substrate. This drying process can take several minutes. In contrast, UV-curable inks dry in seconds—the direct result of the curing process, which uses high-powered UV-lamps. These instant drying characteristics of UV-curable inks permit high-speed printing, whereas high-speed solvent systems require excessively large dryers to speed the drying process.

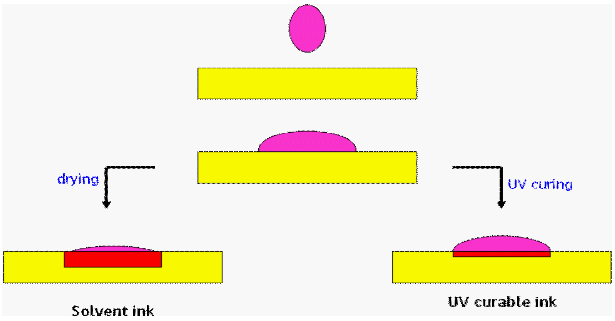
Wider range of substrates

Unlike aqueous, solvent and oil-based inkjet inks, UV-curable inks can be printed onto almost any substrate, both flexibles and rigids, both coated and uncoated. Examples are papers, plastic substrates such as vinyls, polycarbonate, polyesters, etc, but also textiles, wood, glass, ceramics, etc. The only exception is very smooth materials or polished surfaces with very little surface texture. However, even in this case UV-curable inks can be used after applying a primer.

The benefits of printing directly on rigid surfaces such as glass and wood are twofold. First, the mounting step is eliminated thereby increasing productivity and saving money. Second, creative possibilities increase—not limited to a white (paper or vinyl) background.

Colour consistency

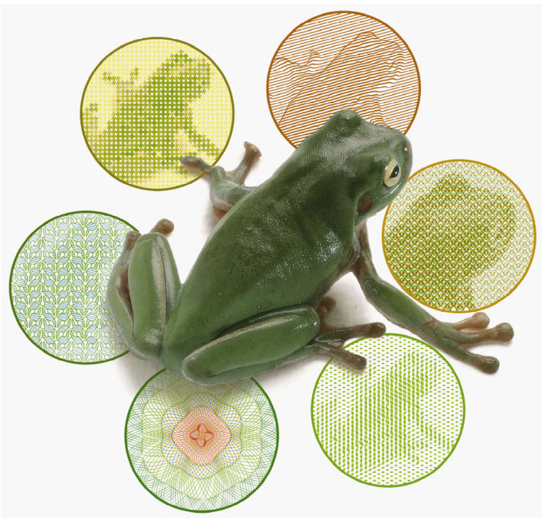
Due to the slow drying of solvent-based inks, these inks dissolve in the substrate so that the colorants actually mix with the media rather than lie on its surface. In contrast UV-curable inks are being cured so fast that the ink droplet is more on top of the substrate. As a result, colour is more consistent from substrate to substrate and less ink is needed to cover the same image area.



Ecologically friendly

During the UV curing process—the interaction of the ink with a strong UV light source—the ink hardens instantaneously. As a result, the entire ink droplet is being solidified. That means nothing is released into the atmosphere. This coupled with the fact that most UV-curable inkjet inks contain no solvent(s), means no VOCs (Volatile Organic Compounds) are released. This is especially appealing in countries where strict environmental legislation applies and where ecological solutions can also result in financial benefit.

In contrast, solvent inks release 80 to 90 percent of its ingredients into the atmosphere as vapours during the printing process. Plus, more solvent inks per square meter of substrate are required to achieve the same coverage (approximately 12-14 millilitres (ml) of solvent inks per m2 is used in comparison to only 8-10 ml of UV-curable inks).



Less ink consumption per m^2

One criticism of UV-curable inks is that they are generally more expensive than solvent inks. As UV inks proliferate the market, their cost will decrease. However, the cost of operating a UV system is actually lower than solvent systems for a number of reasons. First, because UV inks dry so rapidly UV systems are faster, therefore they yield higher productivity. Second, they print on any paper and any surface, so they do not require more expensive inkjet coated paper to produce optimal results. And because they can print on rigid materials, mounting can be eliminated for a number of applications. That saves both time and money. Third, greater colour fidelity means more accurate renderings on the first sheet. Eliminating reprints also saves both time and money. And fourth, because only 8-10 ml of UV ink is required per square meter of substrate in contrast to the 12-14 ml required for solvent systems, ink consumption is significantly lower with UV systems. The slightly higher cost of UV inks, therefore, is more than compensated for as a result of its productivity, versatility and quality advantages.

Continual Improvements

Solvent ink is a mature technology. UV-curable, however, is still undergoing a great deal of R&D to further optimize its properties.

- Moulding/Stretching characteristics
  UV-curable inkjet inks are ideal for a wide variety of printing applications onto flat or curved surfaces—labels on pots, bottles and curved containers, for example. However, typically they are slightly less flexible than solvent inks. So for applications that require a great deal of stretching, solvent inks generally perform better. For example, they more readily accommodate certain vehicle wraps where the graphics need to be moulded around wide curves that require stretching the vinyl.
- Adhesion
  Since UV-curable inks are mainly on top of the substrate (instead of being dissolved into the substrate), the interaction between the ink and the substrate is weaker than in case of solvent inks. As a result adhesion on certain substrates can be improved (e.g. polypropylene, polystyrene, etc.). Furthermore, effects of the UV radiation are cumulative; if an ink film is over-cured, it can become brittle and flake off. This depends on the type of substrate and the colour (see “Conditions Affecting Adhesion,” page 3) and is not a frequent occurrence.
- Outdoor durability
  Generally, the same pigments are used for solvent and UV-curable inks. However, the working mechanism of true solvent-based inks is that the solvent partially dissolves into the substrate so that the colorants actually mix with the media rather than lie on its surface. Thus, the pigments are better protected against light fading. In case of UV-curable inks the mechanism is different. Here the ink droplet stays on top of the substrate. While this offers the advantage of greater colour fidelity and consistency from sheet to sheet, solvent inks are generally more durable.

Advancements in UV-curable Inks

Because of their many advantages and future potential, Agfa Graphics has chosen to concentrate its Research and Development on UV-curable inks. This commitment has given the company an edge in the quality and durability of its UV product line. There are two important reasons why Agfa Graphics is and will stay successful in UV-curable ink development: 1) the company's chemical roots provide an extensive knowledge base for advanced ink formulations, and 2) Agfa Graphics makes its own, dedicated inks, that are optimised for Agfa inkjet engines. Very few other companies can make this claim.

Low odour

The ingredients used in Agfa's UV-curable inks have been specifically selected to have low toxicity for safe handling. These compounds are also selected to have very low irritants. Like all inks Agfa's UV-curable inks have an odour. However, once cured all volatile ingredients are polymerized. Therefore, UV-cured products are far less pungent than solvent-based inks.

Engine compatibility

Agfa's :Dotrix presses (labels, packaging and document printing), M-Press (high-speed flatbed applications) and :Anapurna wide format systems cater to a wide range of applications. Agfa-made UV-curable inks achieve the highest possible quality and productivity because they are engineered to the architecture and target applications of the respective engines.

Ink Characteristics

Agfa's UV-curable inkjet inks are stable, allow fast curing and are easy to handle. The excellent jetting performance and good adhesion on a wide variety of substrates enable a wide range of applications. The high image quality, vibrant colours and perfect edge sharpness combined with good outdoor light stability guarantee heavy duty industrial printing results.

Research & Development

Agfa Graphics engages in a two-pronged parallel development process. The first is concentrating on the ink formulation; the second pays strict attention to the interaction with specific printing platforms. This gives Agfa the advantage of being able to matching its inks to the demands of its inkjet engines.

The ink formulations are the result of an extensive iteration process between engine and ink technicians which finally yields a dedicated ink set for each of Agfa's inkjet printers and presses. During this process all ink properties are optimized:

- Jettability
- Curing properties
- Adhesion to wide range of substrates
- Durability, shelf life, etc.

By using the highest quality pigments and advanced, state-of-the art polymeric dispersants, photo-initiators and other ink ingredients, Agfa is able to obtain the optimal ink characteristics:

- Largest colour gamut
- Sharp vibrant colours for indoor and outdoor applications
- Uniform gloss
- Good adhesion on a wide range of rigid and flexible including wood, metal and glass, as well as coated and uncoated substrates
- Excellent light fastness, chemical and abrasion resistance
- Low odour

On the Drawing Board

UV-curable Inks

Because UV-curable inks are still in a development stage, improvements such as flexibility, adhesion and outdoor durability are on the horizon. Further developments will bring special inks such as unusual colours and special-effect inks.

The UV-curable inks on the market today are free radical curable inks. Cationic UV-curable inks are in development by some ink companies. The cationic curing mechanism has the advantage of not being quenched by oxygen. Furthermore, these inks provide even fewer odours. However, they are sensitive to the relative humidity of the environment. Cationic UV-curable inkjet inks are in their early stages and expensive because of the advanced cationic monomers which are being used. These types of UV-curable inks are expected to be applied for niche applications.

Beyond UV

New radiation technologies will also enter the arena. An example is EB (electron-beam) curing. The energy output of the electron beam is sufficient to start the polymerisation process without the need of a photo-initiator. The price of the electron beam equipment is currently however much higher than of UV-curable equipment.

Future of Inkjet

The technological evolution towards faster printers, improved print heads, cheaper and more functional inks and media, and more advanced software will continue. This will result in a further growth of inkjet printing in the coming years at the expense of analog printing techniques. Besides graphical applications inkjet technology can also be applied for numerous other applications. Print heads will continue to become faster, more accurate, cheaper and more reliable.

The “inks” will become more and more functional and can in principle be anything as long as it can be jetted through the print head. A few examples of non-graphical inkjet applications are printed electronics and displays, 3D printing as well as bio-medical (life science) applications. In the long term traditional inkjet printing applications will only be a small part of all inkjet applications.