FEATURE

UV in Inkjet – Powering Forward

By Sean Smyth, Ph.D.

UV inks and varnishes/coatings have an established niche within printing and packaging markets. In 2013, the market reached volumes of around 60,000 metric tonnes of ink, in addition to 82,000 metric tonnes of coatings. However, this represents a small fraction of the total 3.2 million metric tonnes consumed that year. The volumes are growing, with uptake of new lower energy "Fast UV" systems on sheetfed presses growing strongly, particularly in Japan where the energy usage is under close scrutiny following the Fukishima power concerns. It is growing in narrow web flexo and in wider systems where wet-on-wet trapping with UV and electron beam curing is growing.

However, the fastest growing sector for UV is in inkjet—which is also where the highest prices are paid for inks by end-users, although the supply chains may be quite complex and there can be several intermediaries between ink manufacturer and user who claim a share of the value.

The average price per kilo is higher for radiation-curing inks than for other inks in analog printing as well as inkjet. The ingredients tend to be more expensive with oligomers and monomers more highly priced than resins, oils and solvents and, in some cases, water. UV-curing inks also incorporate photoinitiators that can be very expensive, particularly for low-migration versions. They are used because they can provide significant benefits to the broader printing process. The biggest advantage is the instant-curing capabilities that allow subsequent finishing processes to be carried out immediately, with no delay waiting for drying. There can be efficiencies in energy use over some hot air systems, for example in sheetfed metal decorating. The inks are very stable on press and there is no drying or skinning in the duct or ink reservoir.

All the ink components remain in the printed ink film, making it suitable for food and tobacco packaging where there may be contaminants migrating into the product. The ink cannot penetrate into the substrate after curing, so there is no effect of color dry-back. Varnishes can give very high gloss levels, when required. Generally, a very sharp result is achieved as the ink dries before it has a chance to

FIGURE 1

Print and packaging UV inkjet printing market by application—2008-18 ($ billion constant 2012 values)

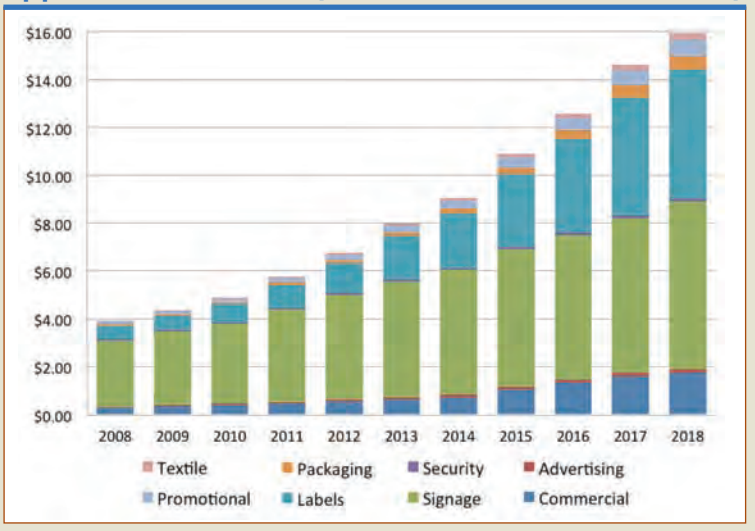
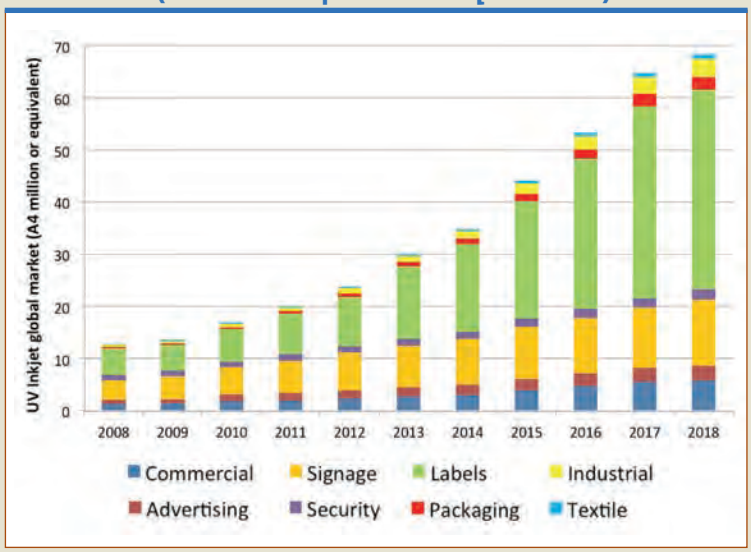


FIGURE 2

Print and packaging UV inkjet printing by application —2008-18 (A4 million prints or equivalent)



spread and there is no contamination from spray powder, giving a cleaner print and operating environment. With UV varnishes, different gloss levels, tactile finishes and drip-off effects can all be realized. The film can be very durable, in some cases removing the need for a separate varnish or laminating protection. Inkmakers can fine-tune formulations to provide excellent adhesion, with varying degrees of flexibility and scratch or squalene resistance, as required.

These advantages are also applicable in inkjet printing, with the stability in the head a key advantage in increasing the reliability of printing without any drying effects that can lead to blockages and downtime. Before the introduction of recirculating heads, this was a key benefit outweighing higher ink costs in many applications. Inks can be formulated to print well on almost any substrate, both absorbent and non-porous. The first use was in outdoor signage applications on wide-format and flatbed printers where good adhesion to board, metal and plastics, and with high lightfastness that often meant a separate laminating stage could be eliminated, thus reducing the overall cost of production. Other benefits became apparent, with the environmental advantage of no volatile organic compound emissions driving adoption rates in North America and Europe where the push to become more sustainable and "Greener" has grown.

Smithers Pira published the "The Future of UV Inkjet Printing to 2018" report in 2013. The report explores developments in technology that are forecast to shape the future of the market to 2018, and breaks down the sector by key markets, end-use output, equipment and inks/varnishes.

There are many categories of equipment that employ UV inkjet. The Agfa Dotrix and some early Miyakoshi models used UV inks in high-speed, single-pass presses, but this sector now has moved to water-based inks. The main sectors are wide-format and flatbed for visual communication applications with some movement into packaging and narrow web machines for labels. UV inkjet is also used in some of the new high-quality sheetfed presses; there are many bespoke integrations and a sector showing considerable promise for direct-to-printing of bottles, cans and rigid, irregularly shaped packaging. There is considerable growth in the value and volume of this print, shown in Figures 1 and 2. These show the producer markets for UV inkjet printed products. In value terms, this is the value of the printing, not the final retail price of the item. The chart is plotted using constant value U.S. dollars—2012 values that strip out artificial inflation and currency exchange factors, allowing valid comparisons across time and geographical regions.

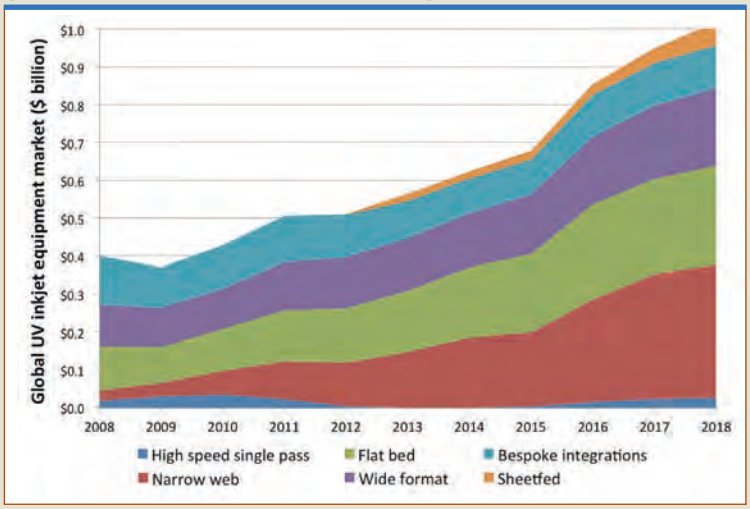
Smithers Pira sizes the value of UV inkjet printing equipment at more than $562 million in 2013. This value will almost double in real terms by 2018 as the levels of productivity, quality and reliability improve and the range of products broadens.

There have been major developments in equipment and, importantly, ink formulation. UV inkjet uses piezo heads exclusively and the head manufacturers—Xaar, Fujifilm Dimatix, Konica Minolta and Ricoh—have improved the reliability and consistency of their heads. The latest generation of Epson's PrecisionCore micropiezo heads are used in the SurePress L-6034VW press, the first Epson inkjet machine to use UV inks. Equipment manufacturers mount the heads into a wide range of printers and presses.

In addition to flatbed, there are roll-fed and hybrid wide-format UV inkjet printers. At Fespa in Munich during May 2014, Océ added new machines to their wide-format inkjet portfolio, the Arizona 6100 series. These are two top of the range flatbed UV machines—the 6160XTS and 6170XTS. Each is capable of 72-155

FIGURE 3

UV inkjet equipment sales by type—2008-18 ($ billion constant 2012 values)



square metres per hour with a bed size of 2.5 x 3.0 m. The bed contains pneumatic registration pins to ensure quick and repeatable loading of rigid media in the correct position, which is important when tiling a large image. There is a high-flow vacuum system for effective pull-down of even warped media. Automated print head maintenance provides hands-free print head cleaning in under 25 seconds per color to maintain consistency. They use Océ's VariaDot imaging, delivering ink drops from 6 to 42 pl to optimize image detail and smoothness, with light cyan and light magenta. Print sharpness and print geometry over the whole bed is further improved by actively mapping the table and adjusting the pixel placement for each individual machine—the so-called Active Pixel Placement Compensation. The 6160XTS is six-color, while the 6170XTS includes white. Océ reported sales of the 6170 to print shops in Switzerland, Belgium, Norway, Italy and the Netherlands.

Above the wide-format is the higher performance flatbed sector, offering speeds up to 1,500 square metres per hour. They are used for rigid substrates loaded onto a large bed (usually 1.6 v 3.2 m) that moves under the heads (which may also move in some cases). The cost of these machines runs to well over a $1 million for the highest specification models that include fully automated loading and unloading systems to maximize productivity. Inca Digital effectively invented the sector with the Columbia around the turn of the century and has been pushed to innovate by EFI, Durst and HP Scitex. Agfa offered the MPress, a hybrid inkjet/screen machine, but this was discontinued in 2012.

At the Interpack 2014 show in May, HP announced it is targeting corrugated materials with new inkjet machines, launching the HP Scitex 15000 Corrugated Press for production of corrugated displays and short-run packaging. This develops the model range with high levels of automation for corrugated, allowing a top speed of 600 square metres per hour on a bed size of 1.6 x 3.2 m using UV-curable inks with 312 HP HDR300 piezo print heads, 52 per color. The press features the high dynamic range function that varies the imaging mode and droplet size according to the image type. There is an integrated automatic media loader that can handle up to four separate board stacks, optimized for use with corrugated sheets without operator intervention. The press has six colors—cyan, magenta, yellow, black, light cyan and light magenta—and HP claims the inks meet ISO12647-7 (2013) proofing standards. It operates four print modes, changing the passes that allow users to print from 312m^2 per hour to the maximum of 600m^2 per hour, or up to 120 full-size beds.

At Labelexpo in 2013, there were some 40 narrow web label presses on show with the inkjet models dominated by UV-curing machines. EFI Jetrion is the market leader, followed by Durst, Domino, SPG Prints, INX and several other machines. Among the new entrants into UV presses are the aforementioned Epson, with DaiNippon Screen and FFEI/Fujifilm launching new high-performance equipment. There are examples of hybrid flexo-inkjet presses, with UK-based Industrial Inkjet Ltd. offering Konica Minolta UV inkjet print modules, while Prototype & Production Systems Inc. in the U.S. offers the Xaar-based DICEweb that is designed to be retrofitted onto flexo presses.

As sheetfed inkjet presses are launched, there are several UV models. In China, the MasterWorks TCjet sheetfed press range (from Tianjin Taichuan Technology Company) claim several installations. The TCjet 420 is a 420mm-wide sheetfed machine printing in four colors with UV inks using Konica Minolta KM1024i piezo heads. It has an option for a varnish unit, with speed depending on the resolution. The highest speed represents some 6,500 sheets per hour. There are wider

FIGURE 4

UV inkjet ink volume—2008-2018 (,000 tonnes)

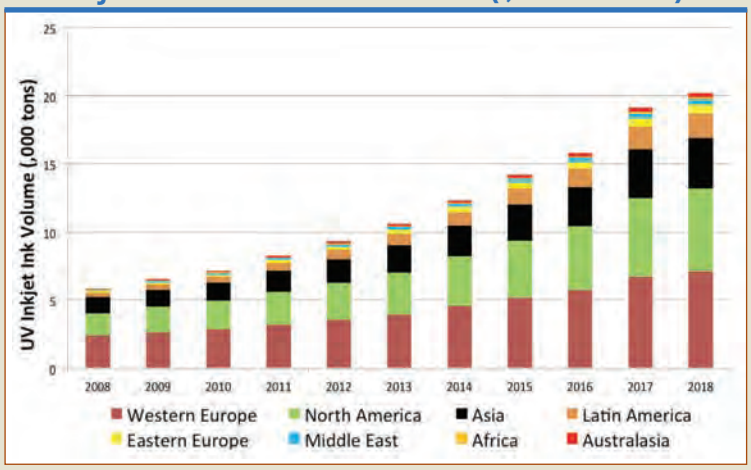
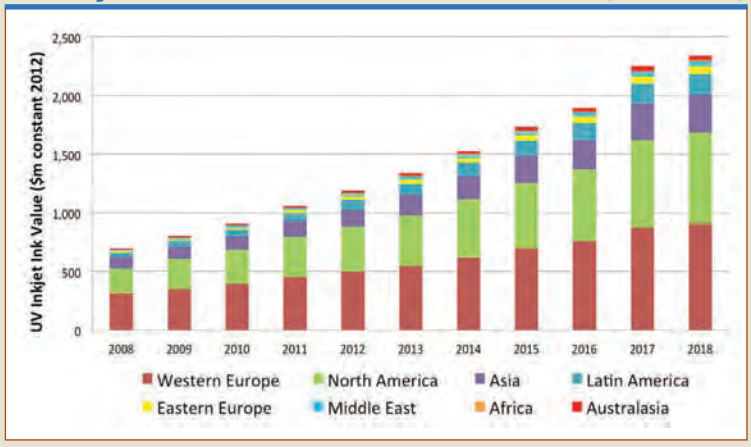


FIGURE 5

UV inkjet ink values at end-user—2008-18 ($ million)



models up to 780mm, where designs consist of straightforward moving conveyors that transport sheets under the fixed heads with an LED-curing unit. The Konica Minolta KM-1 B2 format press is due to be launched in early 2015, while Fujifilm showed a version of its JetPress SX for cartons, the JetPress F that featured a hybrid UV/water-based ink system, but this is not commercially available.

There are a wide variety of bespoke systems and direct-to-pack printers being developed. These can be used to enhance a print, with Israeli manufacturer Scodix producing a range of specialty inkjet-based coating machines that provide digital embellishment to commercial print and cartons. These provide decorative and tactile coatings by laying down a variable thickness of UV-curable fluids, a function it calls "print enhancement." These were first introduced in 2011 and the company reported its 100th installation early in 2014. The cost of the machines varies from some $500 to $900k, depending on model. The Ultra machine always runs at 1,250 B2 sheets per hour, irrespective of coverage. The consumables (varnish and cleaning fluids) are sold by weight. With a typical coverage of 7%, the average consumable cost comes out at $.03 to $.05 (U.S.). Customers are where the functionality is valued more highly than the additional cost and users see significant opportunities, helping to differentiate themselves from other printers to provide new services.

Swiss equipment manufacturer Steinemann Technology has teamed up with specialty UV coating supplier Schmid Rhyner and German printer Druckhaus Mainfranken to develop a large-format digital varnishing machine —the dmax. This can handle sheets up to 1,080 x 780 mm (minimum size 300 x 300 mm) at speeds up to 10,000 sheets per hour. It is targeted at folding cartons and commercial printing with a launch set for later in 2014. It combines proven machine engineering with inkjet at a resolution of 600 x 600 dpi, at a linear speed of 100m per minute to deliver varnishing without pinholes or orange peel effects. The overlapping array of 20 print heads—the identity is not made public, but the inkjet engine is supplied by another Swiss manufacturer (WIFAG-Polytype Technologies AG)—allows the dmax to apply varnish between 4 to 35gsm that can give a range of high-value haptic effects in a single pass. These are enabled by the patented post-treatment of the liquid varnish film before curing.

The range of UV equipment has been advancing significantly in workflow and prepress, including color management; substrate pre-treatment, control and transport; print systems—scanning and fixed heads (there can be hundreds of heads, each needing control in seven- and eight-color

systems); ink pinning and curing with LED systems growing in capability; and finishing both online and off-line. The equipment market development is shown in Figure 1.

There is significant growth in LED curing in UV inkjet—with the instant on-off and less heat serving as primary advantages for the technology, in addition to a smaller drier footprint. EFI reports boosts in productivity for users of their LED-curing systems. They require specially formulated inks that dry using the specific wavelengths offered by UV-LED lamps. There is much development in UV inkjet ink technology, with improved dispersion and stabilization techniques allowing inks to be formulated with higher pigment loadings.

Pigments for UV inkjet ink need to be dispersed to small particle sizes—from some 50 to 200nm in diameter—and this dispersion needs to be made colloidally stable to avoid agglomeration or settling out. The required colloidal stability may be achieved through surface modification forming an adequate surface charge or by adsorption of suitable compounds onto the pigment surface. These could be low-molecular weight derivatives or polymeric dispersants, stabilizing the particles by steric repulsion or by charge repulsion.

Eventually all pigmented inks will settle, but resistance to settling depends on the pigment size distribution, density, surface chemistry and the dispersants used. The settling rate is dependent on particle size and the density difference with the vehicle, making larger particles potentially problematic. Reducing the size of pigments below 100 nm is usually technically challenging for traditional dispersion methods. Ejecting particulates through the inkjet nozzles at high velocity puts many restrictions on the ink properties, particularly in viscosity and surface tension of the ink that can be difficult for low-viscosity inks with high pigment loading and dispersants. Large particle content may plug the jets and channels, causing damage to the print head.

Ink has to be formulated to the correct viscosity when jetted, which can be difficult for high pigment loadings. Some heads operate at temperatures up to 45-50°C to achieve the right viscosity. FujiFilm Specialty Ink Systems has developed inks that use water or solvents as a diluent, commercialized in their Vybrant printer and the Mimaki JS400UV wide-format printers. Such innovations will allow more applications to be opened, further boosting the market for UV inkjet.

End-users paid some $1.35 billion in 2013 for 10,500 metric tonnes of UV inkjet ink, and in 2018 this figure is expected to reach $2.3 billion for more than 20,000 metric tonnes. There is a complex, shared profit pool that includes raw materials, manufacturer, equipment/head supplier, agent, distributor and third-party suppliers. In contrast, ink end-user pricing is forecast to fall as volumes grow and there is increasing competition. It will not be a sharp fall overall—one liter $128 in 2012 falls to $116 in 2018 on average, but as performance increases there are opportunities for ink suppliers to charge premiums for new ink formulations.

Conclusion

UV-curing inkjet represents valuable, fast growing market sectors in graphics and packaging, enabled by the improvements in ink and equipment technology. There will be more innovations and niche markets being enabled and opened by printers and packaging converters in the years ahead.

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Smithers Pira is a global testing, consulting and information services company. In the fall of 2014, Smithers Pira will publish a new market study on radiation curing for graphic arts. For more information, visit *www.smitherspira.com.*

UV inkjet equipment is also used beyond graphic and packaging print, with industrial decoration increasingly using the technology in décor, glass, printed electronics and automotive manufacture. One equipment supplier is Hymmen, a German company making specialized equipment for decorative laminates. They sold their first UV inkjet machine in 2008 and now supply a range of heavy duty inkjet systems based on wide-width, single-pass engines—the Jupiter range that can be integrated into specific production processes.

They are large, wide and heavy machines, providing single-pass inkjet with over 1,000 mm width on wooden board as well as roll-to-roll configurations. These use UV-curing inks with the recirculating heads from Xaar that provide excellent reliability for use in woodworking and similar environments. In May 2014, there were 28 high-performance inkjet decorators in operation with the largest featuring a print width of more than 2,100 mm and a processing speed of up to 50 m per minute. Hymmen says that the capacity of this installed base is some 200 million square meters of laminate per year, a significant inroad into the sector that has traditionally used gravure to print the decorated papers that are subsequently laminated. UV curing makes installations more compact and allows the print to be integrated into a more complex conversion process.