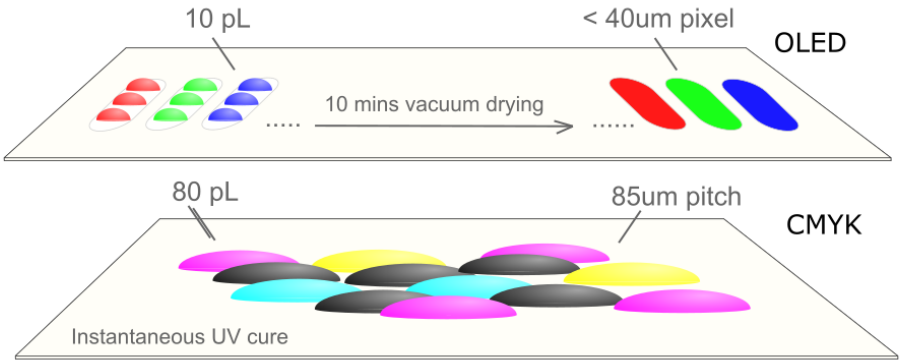
Crossing the Corrugated Chasm – A Personal Perspective

Recently my daughter came home from school and started telling me about how she'd learned the differences between additive colour and subtractive colour. She told me how the "k" in CMYK sands for "key" and is not simply the last letter in the word black! This reminded me of when I first started at Sun Chemical to work on graphics arts print applications after spending the first part of my career working in organic light-emitting diode (OLED) materials for university spin-offs. Moving from leading projects at Cambridge Display Technology to print polymer-OLEDs to working on Sun Chemical's Digital Printing Systems initiative might have seemed almost a backwards technological step to some, but it was a giant leap in terms of proximity to market and printer size. It also meant I had to tackle a lot more chemistry than previously. Indeed, if it was not for my extremely tolerant new office mate, Mr Andrew Balch, I might not have been able to get going so fast. Thanks Andy.



You'll be glad to hear that this article is not about my chemistry knowledge at the time, or lack of it. What is relevant is what catalysed my personal journey: the excitement of working on a printer designed to go 100m/min. After working for several years on printing displays using multi-pass printers, where we might process something like 10 sheets of 350mmx350mm in a single shift, the idea of producing 6000 1m by 1m sheets an hour of was tremendously exciting. I was thrilled to get the chance to contribute!

I finally joined the FastJet project in May 2007, whereupon I discovered the next DRUPA show was just a year away and it had been three years since Inca and Sun had demonstrated a 500mm wide prototype. No Pressure then... The market would be keen to hear the progress, beyond the public announcement of the 'Alpha' machine, installed in the UK (at Jardin Corrugated Cases), as speculation among industry observer confirms [1]. After my initial training on how to make a UV inkjet ink I got stuck in with visiting Cambridge to found out more and I was quickly accused of having a "PhD in cutting up cardboard" when I came home from Inca more than once with 30 or more 1200mm sheets to cut test patterns from for various measurements.

The FastJet used UV inkjet inks in Dimatix Spectra S-class heads. I knew the Dimatix heads from my OLED work but had never seen so many in one place! With 4 or 5 rows of head stitched to give 300dpi, a fully populated machine had 480 print heads. The screenshot from a promotional video can be seen below. Despite the differences in speed, scale, chemistry and substrate, there were some common challenges between OLED and corrugated printing that have since become familiar and repeating themes over the years.

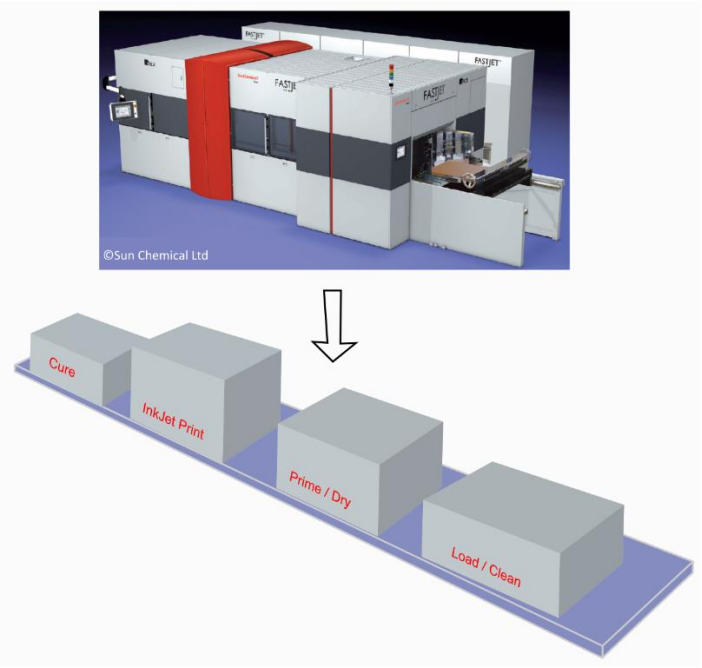
Surface preparation was one, drop placement and cross-process uniformity are the others. In OLEDs the aim had been to get every single drop to within +/- 5um with ideally less than 2% volume variation and get it to dry flat across the print area. Substrate treatment by UV-ozone or by plasma treatment was standard to help that objective, as was lowering the head height to < 0.5mm. When I think back now to FastJet, the challenge was really to get enough drop spread to hide the fact that it simply was not possible to get 12,288 nozzles per colour firing to +/- 5um, especially when the height needed to be 2.5mm to reduce the chance of head crashes. It was more like +/-40um and for this reason, providing a primer became crucial to controlling print quality of the output. Not just that, it helped minimise the UV odour from any residual un-cured UV monomers too. That Autumn I gave a talk about it at my first IMI conference, and was left feeling that perhaps I had failed to explain it properly. It seemed that some had the opinion that if you needed to 'revert' to flexo primer then somehow you'd not done it right.

So here comes the first learning about how to cross the chasm: *Don't expect inkjet to be able to solve every problem - combining available processes is the best way to address industrial inkjet applications.*

So, what happened by the time Drupa came around? Well, two more machines were installed for starters. The Beta printer that I had been working on was placed in the UK, whilst the first 'production' press had made it to Dusseldorf. Not at the show itself, but at a customer nearby at interested parties were invited to visit by bus. We also had a new primer to address a wider range of liner materials, including the most difficult double-coated boards. The photos below reveal the print quality that could be obtained from FastJet during this period of optimisation. The centre image shows a cut-out piece of b-flute bard about 20cm wide. The left image shows the dot visibility with the 80pL drop size, whilst the image on the right compare the gloss differential with and without the 5th (clear) ink being used.

The residual challenge was one of drying the water-based flexographic primer required to even out the non-uniformity of the hugely variable paper-based packaging. Within the confines of the printer 'box' it was difficult to introduce enough hot air handling to do this, and drying systems suppliers were not yet experienced in inkjet specific solutions.

This leads to the second major learning: *When making an industrial inkjet printer, then design outside the box: keep the architecture modular in the print direction because there's likely to be something you have not thought of that might need adding later, either before or after the inkjet.*



As it turns out, my first Drupa in 2008 was where the Kyocera KJ4 and Fujifilm Samba started to make their now well-established march into industrial inkjet applications. The rather impressive Miyakoshi printer using UV inks was still only half the speed of FastJet but offered a glimpse to the future in terms of print quality expectation. Both heads were based on the highly integrated print head concept using roof actuators and 2D nozzle arrays with drop sizes < 10pL.

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Apart from the obvious quality benefit, compared to stitched arrays of lower DPI heads, the newer technology reduced the complexity of print head alignment. That said, even the latest heads still had the same challenges when it comes to missing nozzles, which is something single-pass printers have struggled with for years. Yet, when I approached vision system manufacturers during Drupa to get their advice on how to detect missing nozzle inline with a 100um resolution over a 1m width, not many could help me. These days, it is only with the mainstream adoption of inkjet into high speed production that such challenges get addressed so that nozzle health can be monitored and mitigated. The decreasing cost per nozzle also introduces the possibility of redundancy, as exemplified by the HP approach. That leads to lesson 3:

Nozzles will fail eventually. Successful industrial printers will manage cleaning automatically and utilise modular design principles to enable rapid head replacement and avoid manufacturing delays.

So maybe you're wondering why I keep harking on about in a printer that isn't sold anymore. Well that's really where we get to the most important lesson. Other than the fact that 2008/2009 were generally quite bad years for anyone selling capital equipment, there were other reasons that FasJet did not continue. The most prominent of those was related to customer readiness. At the time of project conception Sun Chemical was seeking to address a need that some corrugated converters could see the potential of, but that did not mean the market was ready to invest millions of $s into brand new technology that they still did not fully understand or trust. The integrated workflow solutions also did not exist to help fill the machine and maximise the return on investment.

Lesson number 4: *It takes time for established markets to come around to the digital value proposition and to grow the new models to fill the machine. Being the first to market can be as much pain as it is an opportunity.*

Although there has been a steady growth since 2008 in application of multiple-pass options for printing onto corrugated sheets, in 2018 we now see many single-pass printers in the market, such as from Barberan, Durst, EFI and HP. The first 3 have tended to follow the rules above quite well. The first real market progress was made by the Barberan Jetmaster series printer, which uses UV-cured ink has a water-based pre-coat station with drier, both positioned outside the main inkjet enclosure. Using a pre-coat to minimise ink penetration no doubt helps obtain the approval for more sensitive applications. The EFI Nozomi C18000 is also using UV-curable inks and has pre-coat too, thus providing capability to print a wide selection of liners materials.

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The HP C500 and Durst Delta SPC-130 are a bit different since they used water-based inks, as do the Sun Automation CorrStream series printers. The 'revolutionary' HP [3] uses a jetted bonding agent, which is an approach proven in their production roll-to-roll printers, but by their own words "limitations may apply" to the materials it may work with. The CorrStream looks the most like the FastJet, which is interesting since they supplied the vacuum bed for the Ina-built printer. The advantage here is that they can leverage their position in the market to make sure the in/out board handling is fully integrated. This was a challenge for the first FastJet installs. The Durst takes the modular design concept and makes it look tidier than my schematic, providing priming options as well as feeding and stacking and it is the fastest piezo inkjet machine available. Indeed, it is the only machine to the Author's knowledge that advertises faster linear speeds than Sun/Inca's FastJet:

Manufacturer	**Model**	**Ink Type**	**Print Head**	**Speed**	**Addressability**	**Ref**
Barberan	JetMaster	UV	Seiko	55m/min	360x360 dpi	[4]
EFI	Nozomi C18000		Seiko	75m/min	360x720 dpi	[5]
Sun Automation	CorrStream 66 Series	AQ	Kyocera	70 m/min	600x300 dpi	[6]
				55 m/min	600x600 dpi	
HP	C500		TIJ	75m/min	1200dpi	[7]
Durst	Delta SPC-130		Dimatix	120 m/min	800x?	[8]
Inca/Sun	FastJet	UV	Dimatix	100m/min	300x200	-

So hopefully the history lesson now makes sense. Corrugated printing is now mainstream, but it took time to get there and there were one or two casualties along the way. As technology developers we love the challenge of solving problems, but as someone remarked to me recently sometimes we need to wait until the market is ready for the solution. Perhaps this could have applied to high speed single pass corrugated printers in 2009!

References

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