Primers for UV Jet-Inks

Alexander Grant, SunJet, Bath, England, United Kingdom

Abstract

As the range of applications for UV jet-ink printing expand, the diversity of media evolves at a similar rate. To adapt to this, in many situations it is possible to successfully modify ink chemistries or process conditions. However, in the case of medium to highly porous media, such as paper, output issues can remain. In particular, penetration of UV jet-ink can lead to insufficient optical density, poor image quality and high residual odour due to incompletely cured materials. In addition, equivalent image quality is often demanded across a selection of papers of varied nature. This article describes the usage of classes of primers that can be applied to papers and used in conjunction with UV jet-ink. In doing so, ink penetration can be minimised and controlled image quality may become possible. Specific examples are given for paste-UV and water-based UV primers which due to their curable functionality make them highly compatible with UV jet-inks. Furthermore, this approach to controlled ink wetting on porous media can be extrapolated to non-porous media such as plastic films. In doing so, this presents a combined matching of ink and primer chemistries to achieve desired wetting characteristics. In turn, this can help fulfill future demands in this market as it evolves.

Introduction

Ink-jet printing has developed from initial stages of marking and coding applications such as sell by dates and bar codes, to state of the art commercial graphic outputs in point of purchase display, textile and packaging printing. As print-head technology and speed of printing have improved so too has the range of media diversified.[1]

UV inks have accelerated away from other jet-ink technologies in their performance. This is mainly due to their excellent jetting reliability and end use performance in comparison to water, solvent and oil based counterparts.[2,3]

However, as new markets emerge, importantly in major traditional printing segments such as packaging, the inks must respond to a highly varied range of media that they are inherently not suited for. In particular, there is considerable difficulty in using UV jet-inks successfully on papers and other highly porous media. This is primarily due to penetration of uncured material through the substrate. As a result of this, high degrees of cure are impossible and a strong residual odour may be observed. In addition, pigment can also drive through resulting in colour loss and poor optical density. From the printers' perspective, they are unlikely to undertake the lengthy and cumbersome process of an ink technology switch over to say water or solvent-based alternatives. From the end–users' point of view they may be reluctant to change substrate that is used with success in a conventional printing process. In summary, when faced with a variety of media there is little chance of achieving uniform print quality (see Figure 1).

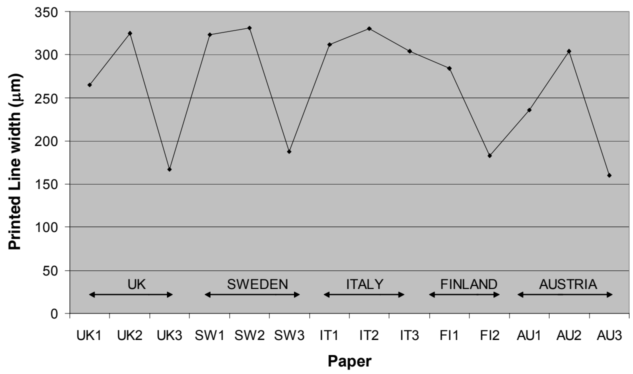


Figure 1. Printed line-widths of a single UV jet-ink printed on a selection of European packaging papers.

A possible way round this dilemma is the introduction of a pre-treatment process to the media. This could take the form of a corona, atomic plasma or aerosol application.[4] However, this may be somewhat limited to non-porous media such as plastic films, including acrylic and polyester.

For paper media, this approach tends not be as successful; instead application of a primer can be an attractive option. By providing a positive sealing effect on the pores of the media and facilitating ink wetting control, it is possible to drive towards uniform image quality across varied substrates.

Primer Technology Options for Porous Media

Water and solvent-based chemistries are common for paper coatings.[5] These are widely used in office type ink-jet papers and generally are applied and dried off-line so the printer receives ready to use materials. This is not an ideal approach for dealing with a diverse range of papers requiring a fast turn around from supplier to printer to end-user, where an in-line approach may be preferred. With this process, water and solvent-based primers are less attractive. High levels of residual water need to be removed prior to printing, causing speed reduction; environmental considerations may also play a part. In addition, there is often a lack of interaction between the coating and the printed UV ink resulting in poor adhesion. A way round this is usage of UV curable primers.

In this situation, the curable material can sit on the surface of the paper and when UV ink is printed and irradiated with UV light, the whole chemistry binds together to form a coherent, well sealed system.[6] Selection of materials for such a purpose is somewhat restrictive as, in the case of the UV ink formulation, components have a tendency to migrate rapidly through the media. This may be overcome by combining the curable moieties with waxes to form a paste-UV primer or with water-based oligomers to form a water-based UV coating. The latter is shown schematically in Figure 2 below.

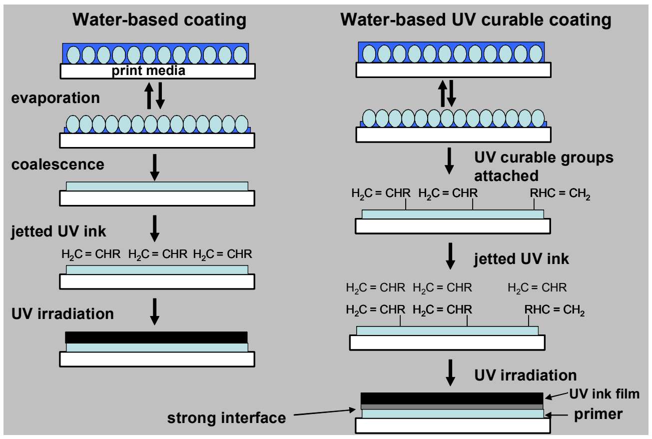


Figure 2. Water-based and water-based UV curing coatings printed with UV jet-ink.

The paste-UV primers are a combination of wax and curable components, resulting in a mixture which is viscous/paste –like in nature at room temperature. Upon heating, the waxes melt to produce a homogenous low viscosity fluid. After application and cooling, the wax can solidify rapidly giving excellent paper sealing whilst the curable material is available for reaction with the UV jet-ink.[7]

Primer Influence on UV Jet-Ink Spreading on Porous Media

The SEM images in Figure 3 highlight the difference that application of a paste-UV primer can have to the "open-ness" of the paper. Sealing the paper pores and binding the fibres together is a fundamental task for the coating but this is just one aspect of the primers role.

Control of how the ink wets on the new surface is critical to meet image quality requirements.

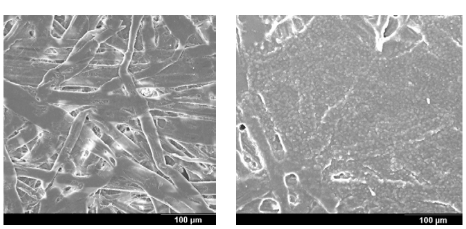


Figure 3. SEM images of uncoated (left) and paste-UV coated (right) paper.

The variance in printed line-width observed across a range of papers in Figure 2 indicated the need for primer introduction. By applying a paste-UV primer to these papers, the line-width data tends towards a uniform value. See Figure 4.

Within this, it may be necessary to achieve higher or lower degrees of wetting. To do this, additives that can alter the coating surface energy or interact in a certain manner with the UV jet-ink are valuable. At the correct concentration, surface active agents that can migrate rapidly to the primer-air interface are the first point of contact for the printed UV jet-ink. By selecting a low surface energy surfactant it is possible to reduce ink wetting. In contrast, absorbent materials such as calcium carbonate can raise the coating surface energy and thereby promote ink spreading for solid fill areas. The controlling effect of the nature of the coating is illustrated in Figure 5, with a series of line widths.

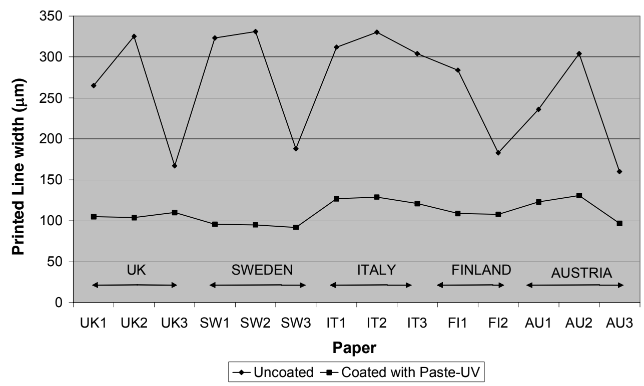
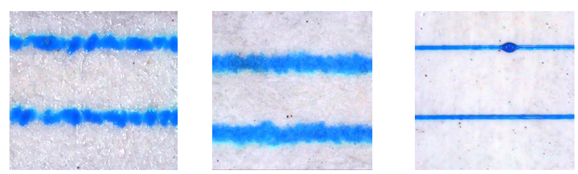


Figure 4. Line widths of UV jet-ink printed on coated and paste-UV coated papers.



a) 195 µm b) 273 µm c) 70 µm

Figure 5. Images of line widths of UV jet-ink printed on a) uncoated paper, and coated with b) high surface energy & c) low surface energy water-based UV curable primer.

Controlled UV Jet-Ink Wetting on Non-Porous Media

Surfactant Selection

With non-porous media such as plastic film there is generally no need to seal the surface to prevent ink penetration. Instead the focus is to control ink spreading across a variety of underlying substrates. To do this it is often possible to use a much simpler primer than that used for porous media.

For example, application of only surfactant to polyester film can yield a major change in how the ink wets.

Figure 6 shows how the contact angle of a UV jet-ink applied to untreated and surfactant treated polyester may be altered with this approach.

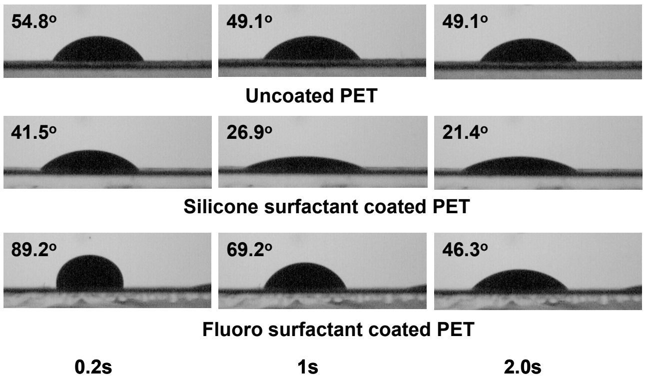


Figure 6. Contact angle (°) of UV jet-ink on uncoated PET (top), silicone surfactant coated PET (middle) and fluoro surfactant coated PET (bottom).

Surface Energy

In many cases this can be rationalized in terms of Youngs' equation; high coating surface energy will promote ink wetting and low will not.[8] In the case of certain surfactants we have found that total surface energy is not sufficient to fully describe the ink spreading that is observed.

Table 1 shows printed line width achieved with PET substrates treated with 4 surfactants.

Table 1: Surface Energy of Inks and Primers and Printed Line Widths

Primers	Primer surface energy (mN/m)	None	Fluoro A	Fluoro B	Silicone
		UV jet-inks containing surfactant			
		Printed line width (µm)			
None	37.38	92.4	93.14	177.46	243.28
Fluoro A	34.64	77.56	73.77	70.49	78.02
Fluoro B	39.34	149.28	141.66	126.14	152.38
Silicone	30.93	145.99	152.99	140.18	167.32
	Ink surface energy (mN/m)	31.38	26.1	29.5	23.7

The surface energy of these coatings was measured by contact angles made with test fluids on model substrates. By using the Fowkes equation (1) below it was possible to evaluate polar and dispersive values for surface energy.[8,9]

$$\gamma_L \cdot (1+\cos\theta) = 2\sqrt{\gamma_S{}^d \cdot \gamma_L{}^d} \qquad (1)$$

Here γ_L is the surface energy of the fluid, θ γ_S^d is the advancing contact angle of the liquid on the solid, γ_S^d is the dispersive component of the solid surface energy and γ_L^d is the dispersive component of the liquid surface energy. Across the range of surfactants there is a good variety of values. However these do not correlate with the observed line widths. Figure 7 shows a plot of printed line widths against coating surface energy for a range of different fluoro surfactant chemistries.

In addition, the data in Table 1 suggests that putting one surfactant in one ink can also have a controlling effect.

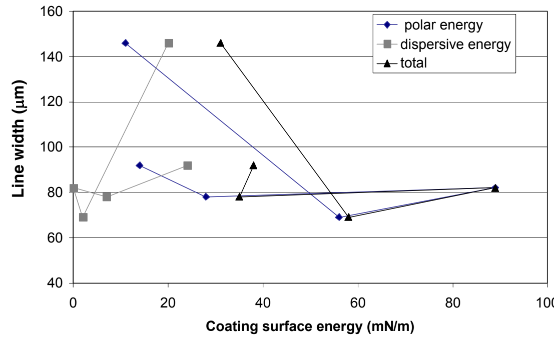


Figure 7. Plot of polar, dispersive and total surface energy of UV jet-ink against line width

The ability to produce very high definition dots through this approach to non-porous media treatment could be important for a range of application areas not restricted to UV jet-inks. For example, in the field of conductive inks it is important to achieve very small dot size and optimize ink spreading.[10]

Figure 8 shows profilometer images of excessive spreading on untreated Kapton media with solvent based conductive ink. By introducing a surfactant primer, the inks spread is minimized and conductivity improves markedly.

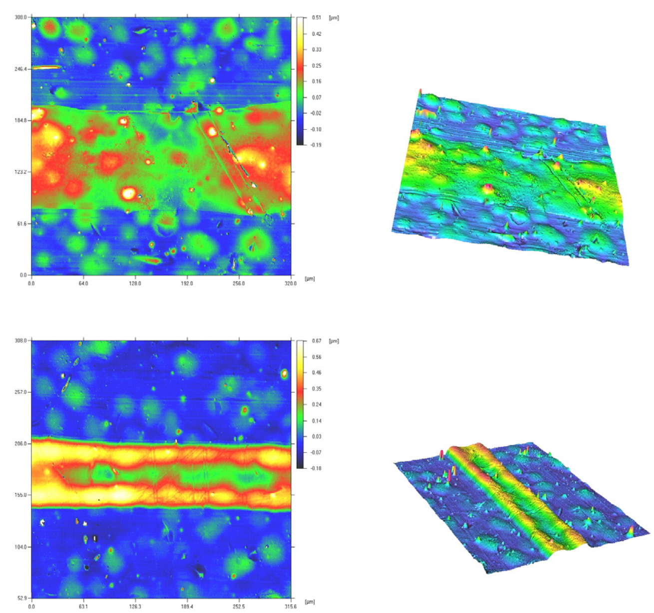


Figure 8. Profilometery of conductive ink on uncoated (top) and surfactant coated (bottom) Kapton film

Process and Application Considerations

The method by which the primer is applied is a major influence on printing speed, machine size, storage and cost. For example, in-line application may be preferable for speed but integration may be cumbersome and costly. In contrast, off-line treatments could impact upon storage and have an effect on shelf life, particularly for UV curable primers. The physical nature of the primer is such that it must be adjusted to the chosen process. Options include spray and ink-jet coating as non-impact processes and flexo, gravure, roller and curtain coating as traditional methods. For each of these options the primer is applied at different weights from $<1g/m^2$ (e.g. flexo) to $>100g/m^2$ (e.g. curtain). In turn, this can have a strong effect on the physical nature of the media. In addition, the primer may need to be made "press-ready" through dilution of viscosity to match the process. For a paste-UV primer it is possible to alter the solidification temperature of the material and rheology at application temperature through formulation modification.

In an ideal situation a single primer would be sufficient to provide desired wetting properties on the media. But this is very much dependent on the physical and chemical nature of the substrate. In some cases, a highly wetting primer may be needed to achieve fill in solid areas; in other situations a low surface energy primer may be needed to provide sharp character definition in text or numerical regions. Further fine tuning of ink wetting and image quality is possible through controlling the concentration and chemistry of the additive.

Conclusions

Given the wide variety of papers that are used in printing, it is difficult to achieve desirable print quality uniformly with a single UV jet-ink chemistry. Furthermore, it is generally a lengthy and cumbersome process to change ink families from a digital printers' perspective. A possible option is usage of a pre-treatment process prior to printing. In the case of coatings, there are several chemistries that are traditionally used but in combination with UV jet-inks these are not necessarily optimal. An alternative to these are UV curable primers such as paste-UV and water-based UV clear coatings. These are applicable to a wide selection of papers and have been shown to provide a good surface seal thereby minimising ink penetration. This can aid in the reduction of odour in the print and give superior optical properties. Furthermore, it is possible to increase or decrease ink wetting according to end use requirements by further modifying these chemistries. In addition, much of this primer technology can be simplified and transferred to no-porous media such as plastic films. By tailoring the nature of the coating to the application process it is possible to gain further wetting control. It then becomes more realistic that a single choice of UV jet-ink chemistry can satisfy end use requirements across a range of different media.

References

1. A. Grant, H. Allen, Proc. NIP 20, pp 784, 2004.
2. A. Grant, European Coatings Journal, May 2004, p44-47.
3. A. Grant, Ink World, May 2004, pp47-51.
4. Coating, vol.37, issue 10, pp.370-374, 2004.
5. J.M. Asua, "Polymeric dispersions: principles & applications", Kluwer academic publishers, Series E: Applied Sciences, vol.335, 1997.
6. WO patent No. 02/0856386.
7. WO patent No. 9954416.
8. A.W. Neumann and R.J. Good, Surface and Colloid Science, vol. II, ed. R.J. Good and R.R. Stromberg (New York: Plenum Press, 1979).
9. R.J. Good, J. Colloid and Interface Sci., 59 (1977), p. 398.
10. Linda T. Creagh, Spectra Inc., Ink Jet Printhead as a Precision Deposition tool in Manufacturing FPDs, Proceedings of SEMICON® China 2004 FPD Manufacturing Conference.

Author Biography

Alexander Grant received a PhD from Cambridge University in 1995 in the synthesis of liquid crystalline polymers for coatings and holds several patents in ink-jet ink formulations. He is currently Project Leader at SunJet, at their headquarters in Bath, UK. This followed the position of Scientist at SunChemical in Carlstadt, NJ, USA, working on ink-jet for computer-to-plate and packaging. Before this he worked as Polymer Scientist with National Starch, synthesising emulsions for paints and coatings.