Photomedia for Digital Minilabs

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Abstract

Digital minilabs can facilitate the enhancement of prints from colour negative films as well as printing from digital cameras and a wide range of digital storage media.

A number of printing technologies have been considered for digital photofinishing including ink jet, thermal dye transfer (D2T2), electrophotography and AgX technology. In the last couple of years a number of photofinishing solutions, based on these technologies, have appeared in the market place.

The expectations of the consumer are that the digital photos will match those produced from colour negative film using AgX technology. The different output technologies will be considered and contrasted to AgX output.

Introduction

The growth rate for digital cameras is currently one of the highest in any market segment. The methods for printing digital photographs are becoming more sophisticated with ink jet proving to be one of the most popular for home printing. There are however, still many alternative printing technologies including thermal printing, electrophotography and AgX printing systems. There are many clever options for home printing with docking stations and ink jet photo printers, with inputs capable of handling digital camera storage systems, smart media, compact flash and memory sticks (figure 1) and also printers with IR detectors, which are capable of wireless printing.

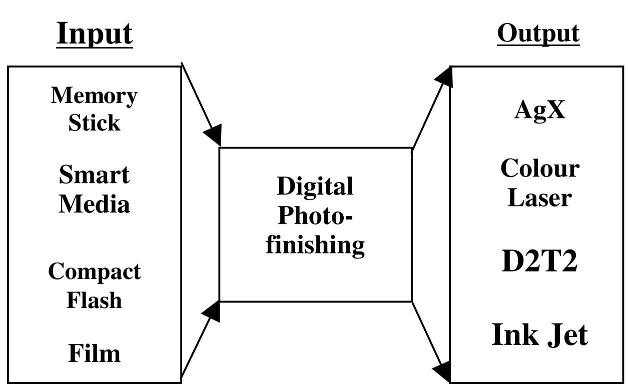

Figure 1

In addition to home printing of digital photos, consumers may prefer to use a commercial digital minilab service similar to that now offered by AgX photofinishing. The output technologies include ink jet, dye thermal transfer, solid and liquid toner-based systems and also AgX digital minilabs. In addition, Fuji have both the Thermo-Autochrome system and the Pictography printer for printing digital photos. The goal for all of these output methods is to produce AgX quality photos. The image quality is certainly good enough; however, the cost for all the systems is high compared with AgX and the image permanence of the prints, for the dye based ink jet and thermal transfer output devices, is not as good as that of conventional AgX photos.

This paper will review the media developments, which are trying to bridge the remaining gaps between digital and AgX photos. The different photomedia types and the coating technologies, used to provide compatibility with the output devices, will be discussed. The colorants are important for image permanence and image quality, and the impact of dye and pigment based ink systems on media design will also be considered.

Photomedia for Digital Photos

As digital photography increases in popularity with consumers the number of photos being printed digitally has grown rapidly in recent years. This has led to the development of digital minilabs that are capable of processing large numbers of digital photos requiring significant volumes of photomedia. The substrate, which is most commonly used for digital photo output[1], is the resin-coated substrate (figure 2).

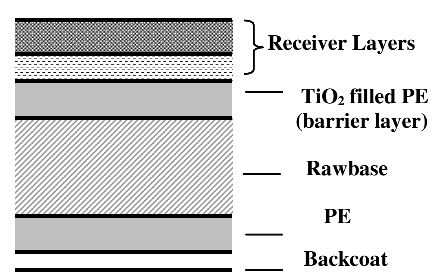

Figure 2. Resin-Coated Substrate

For nearly all of the digital printing technologies and also for most analogue AgX photos, the polyethylene-extruded photobase provides a substrate which matches the look and feel of a traditional AgX photo. This substrate provides a very smooth glossy surface onto which additional layers can be coated. Cockle is not an issue since the PE barrier layer prevents the penetration of water into the paper. The curl is controlled by either adjusting the coatweight of the backside PE or by application of an aqueous backcoat. An alternative media is a paper glossy where no barrier layer is included (figure 3). The rawbase substrate provides additional ink absorption capacity for the different ink systems.

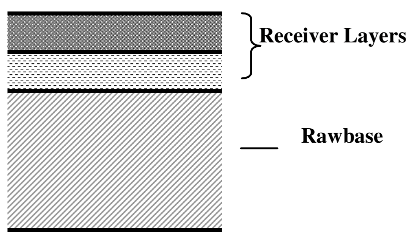

Figure 3. Paper Glossy Photomedia

Digital Media for Digital Photofinishing

The digital photofinishing market is expanding rapidly and many of the traditional AgX photofinishers are involved in the development of digital minilab solutions. In addition, many other competitors in the imaging field are entering this lucrative market. Many of the images are laminated and this provides additional gloss as well as protection from environmental fading.

Electrophotography/Colour Laser
Solid Toners

A range of substrates can be used including a resin-coated paper (figure 1), polyester, or rawbase paper (figure 2). The toner-receptive coating usually consists of a low Tg polymer to provide good toner adhesion.

The image quality of the print is influenced by many factors including media design, particularly the coating, the printer, the toner characteristics, fuser temperature and the dwell time of the printed image in the printer. Higher fusing temperatures and longer dwell times contribute to improved adhesion between the toner and the receptive coating. For most digital output technologies, the colour-media interaction is key; so the interaction between toners and the image receptive coating has the greatest influence on the image quality. The two most important steps for the media design are the transferring and fusing of the toners. Different substrates are used for colour laser printing including resin-coated rawbase, paper glossy and polyester (PET) substrate. For digital photography the resin-coated substrate tends to be preferred since this is closest to the physical characteristics of AgX photos(see figure 4).

The image brightness and quality depend on the fusing process of the coloured toners to the toner receptive coating. The coatings consist of thermoplastic transparent resins with low Tg. Often mixtures of high and low molecular weights resins are used to provide the optimum colour gamut and best image quality.[2] Typical coating polymers include poly-acrylates, polyesters, polyurethanes and polyvinylacetates.

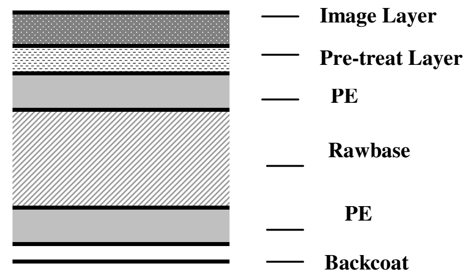

Figure 4. Colour Laser Photopaper

Toner adhesion is a key parameter for good image quality. The toner particles are typically 5-15 µm in diameter and contain up to 90% resin and 5-10% pigment colorant. Some of the most recent printers use CPT (chemically produced toners) technology which have much smaller toners down to particle sizes of 1µm. These give higher quality colour images that are more transparent and have improved differential gloss performance.

The media design must also avoid problems where the back of one print sticks to the faceside of another (blocking). The coating formulation must be fine-tuned to provide anti-block, slip and good toner adhesion properties. To overcome problems of blocking, thermal stability and high coefficient of friction, an inorganic pigment can be included in the coating. Alternatively high and low Tg polymers can be mixed to form a hard/soft polymer system.

Sheet feeding is also important and so the coefficient of friction of the backcoat is important to ensure the photopaper doesn't jam in the printer.

The combination of smaller toner particle sizes with thinner media tends to facilitate the fusing process. Optimisation of the anti-static behaviour of the media, through the design of the backcoat, is also important in order to provide the best digital photo output for colour printers.

For colour laser photopapers, issues include the toner remaining on the surface with very little penetration into the receptive coating (figure 5). This can result in a gloss difference across the surface of the image, due to melting effects caused by the toners. The colour gamut can be reduced, due to the lower chroma of the pigmented toners, and there can also be a reduction in transparency for secondary and tertiary colours.

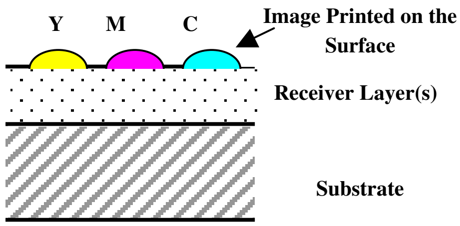

Figure 5. Interaction of Toner with Receptive Coating

Liquid Toners

The liquid toner 'ink system' overcomes many of the problems of solid toners. The toner particles tend to be smaller (< 1µm) and there is less polymer and a simpler formulation where one of the main components is a high boiling hydrocarbon mineral oil which is used to help apply the pigments to the organic photoconductor drum[3].

The image quality produced by this technology is excellent and the problems with having up to 90% of the toner resin (solid toners) present are largely overcome using the mineral oil to help transfer the liquid toners to the receiver layer. The photomedia can consist of a polymer coating on either a cast-coated paper, or a resin-coated(RC) photopaper substrate. The RC substrate is similar to the AgX substrate and so this provides prints which are very similar to silver halide photos. The coating formulation consists of a thin coating of a polymeric material similar to that used for solid toners, which is compatible with the pigments and toner resins applied by an off-set process in the digital printing press. The image is normally laminated producing a very high quality glossy picture. This system can operate at faster speeds than ink jet and D2T2 systems, and can produce more than 5000 (6''x4'') prints an hour. Durability is very high due to the pigment colorants and the lamination of the print protecting the image from environmental deterioration.

Ink Jet

Ink jet has developed as a popular method for printing digital photos. Ink jet minilabs are now becoming commercial. The ink systems, used for ink jet usually contain aqueous soluble dyes with 70-80% water and typically 20-30% glycol as cosolvent to prevent nozzle blockage and keep the printer firing ink[4]. The dye-based inks can be printed onto media, coated with aqueous layers, which are compatible with the ink systems. For ink jet two main categories of coating have been developed. These are swellable polymers, and microporous pigments[1]. Both are compatible with most ink systems although for high ink laydowns and faster printer speeds the microporous systems tend to be more suitable. The drop on demand ink jet technology is limited in terms of speed, however the image quality and colour gamut are better than for most of the other digital printing technologies. The cost and permanence of the images produced by ink jet tend to be higher when compared with silver halide.

Microporous and Swellable Polymer Coatings

The development of ink jet photomedia has probably received more attention than any other media system for digital imaging. A large number of patents have appeared over the last five years. The initial developments were based on gelatine type media, which are quite close in structure to AgX photopapers.

These media provide bright durable images that have good compatibility with aqueous dye-based inks. The swellable polymer media have problems with slow drying and tackiness of the print for some time after printing. For faster printer speeds and at higher ink solvent loadings, there are image quality problems such as bleed and coalescence.

Table 1 shows a comparison of ink jet photomedia to AgX for dye and pigment based inks. The microporous ink jet media coatings were developed to provide instant drying of the inks and to overcome issues with tackiness. The chroma and gloss are not as high as for swellable polymer-based coatings and there can be some issues with the durability of the images on microporous media[5]. One issue for the microporous media is gas fastness. This is a consequence of the relatively open structure and the active surface of the ceramic materials (usually based on silica and/or alumina). This leads to rapid fading of the image, particularly the cyan by O_3 present in the atmosphere. There is a large amount of research work currently focussed on solving this problem for the microporous media.[6]

Table 1. Comparison of Image Properties Ink Jet vs AgX

Properties	AgX	Ink Jet Photopapers	
		Swellable Dye-Based Ink	Microporous Pigment-Based Ink
Gloss	Excellent	Excellent	Good
Image Quality	Excellent	Excellent	excellent
Chroma	Good	Excellent	v. good
Light Fastness	Excellent	Good	excellent
Cost	v. good	Poor	poor
Gas Fastness	Excellent	excellent	good

Compatibility with Pigment Inks

The other advantage of the microporous media systems is that they tend to be more compatible with pigment-based inks. (figure 5) For swellable polymer media the pigments do not penetrate the polymer surface and smudging and smearing of the image can be a problem.

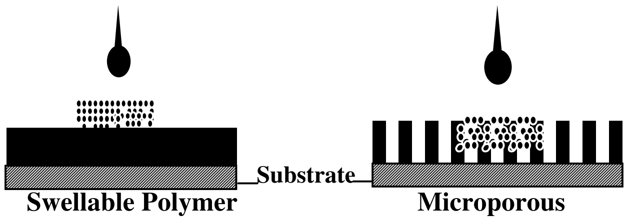

Figure 5. Ink Absorption of Pigment Based Inks

Pigment inks have the advantage of providing durable images under most environmental conditions.

Humidity Fastness

One other problem, for ink jet inks, is that under high humidity conditions the images can migrate. This is a result of the water solubility of the dye systems. For highly soluble dye molecules, with a low molecular weight, diffusion is greatly facilitated. This can often be a greater problem in swellable polymer coatings(figure 6) however, microporous coatings can also exhibit this migration behaviour under extreme conditions.

One solution to the problem is to increase the cationic charge within the coating to fix the anionic dyes more effectively.

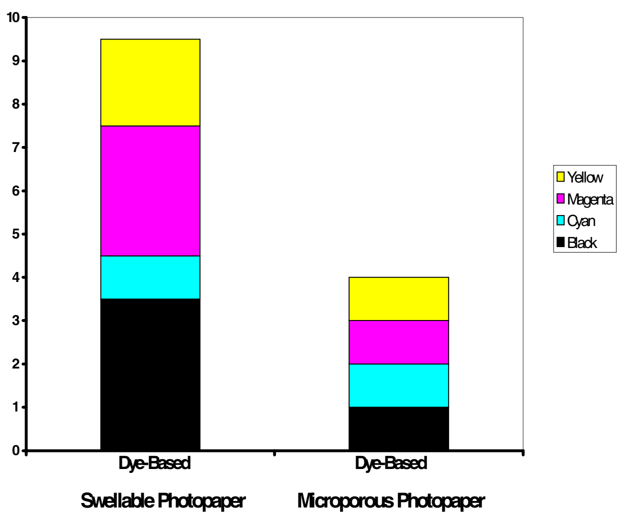

Figure 6. HumidityFastness of Dye Based Inks

Pigment inks, due to their inherent lack of aqueous solubility, generally show no migration under all environmental conditions.

Dye Diffusion Thermal Transfer Printing

In thermal dye transfer (D2T2) the yellow, magenta and cyan (YMC) dyes are transferred from a dye-coated polyester ribbon to a polymeric receiver medium. At the relatively high temperatures occurring during printing the transfer of colour needs to be rapid. Typically the temperature of the thermal head and indeed the temperature of the polymeric media rises to 50°C or above. During the dye transfer the dye ribbon and receiving layer are held in intimate contact under pressure and the heat causes the dyes to diffuse from the donor to receiver. (figure 7) Image formation results when the YMC dyes are thermally transferred into the polymeric receiver layer by a diffusion process.

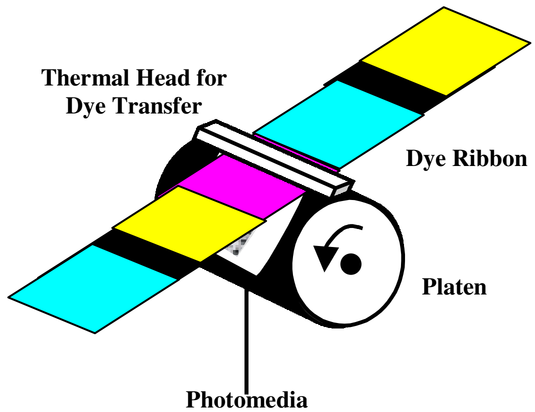

Figure 7. Dye Transfer to the Photomedia in D2T2

The coating layers in a D2T2 printing sheet usually consist of polymers which are laminated onto the substrate. This can be a multi-layer system with a carrier layer and an image receiving layer (figure 8).

The substrate provides the mechanical stability and for digital photo printing this provides the characteristics of a traditional AgX photo. The carrier layer is formed as a foam layer typically consisting of the formulation 90% acrylate, 5% tenside and 5% water. This layer is typically 10-30 µm thick.[8]

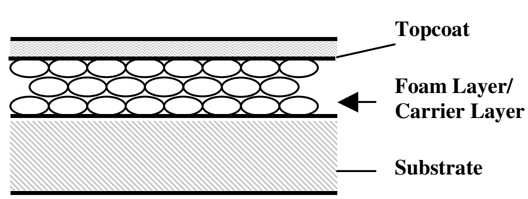

Figure 8. Photomedia for D2T2 Printing

This carrier layer needs to have the following properties:

- Low heat conduction
- Good compressibility
- Gloss
- Surface smoothness
- High whiteness
- Durability
- Good compatibility with image receiving layer

The topcoat closes the foam surface and controls gloss, whiteness, and surface energy. This coating is typically 5µm and can consist of e.g. polyesters or acrylate polymers.

Colour-Media Interactions

For digital minilabs it will be important that the colorant and image receiving layer are compatible. For most of these technologies pigments are the colorant of choice. For solid and liquid toners, as certain ink jet inks, the media must interact effectively with the YMCK pigment based colorants. For most ink jet printers the colorants are water soluble dyes while D2T2 uses solvent soluble colorants or disperse dyes typically derived from dyes used in the coloration of polyester textiles. Thus polymers based on polyester chemistry may be used in receiver layers for D2T2. Durability is one of the biggest problems for dye based systems. For D2T2 the light stability of the cyan is usually worst and for ink jet the magenta is often a problem.

The pigment colorants tend to have very good image durability and are capable of providing a colour gamut, which is as good as silver halide. One problem can be the differential gloss that is observed on printed images. The dye-based systems tend to give a much more uniform gloss for printed images.

The dye-based colorants are more readily matched to the image receiving layers. This improved compatibility leads to a larger colour gamut, excellent image quality, and good colour gradation for digital photos[9]. Pigment based technologies such as ink jet and liquid toners have come closest to matching the compatibility of dye based inks.

Summary

Digital photofinishing is growing at a quite rapid rate and there is a requirement for a competitive output solution to replace the existing photofinishing labs. In the end an AgX based solution may provide the most cost effective answer and also provide the consumer with a digital photo no different to that which is currently available from the analogue based minilab systems.

Ink jet appears to be the most versatile of the current technologies but it is still quite slow and relatively expensive compared to AgX. Also to match AgX the image permanence of dye-based systems must be improved. One option is lamination of the prints to solve differential gloss problems in the toner systems and to protect the images from the influence of the environment such as light, gas and humidity.

D2T2 provides high quality output that is suitable for a number of applications including kiosks, event digital photos eg. Theme parks, where water fastness may be important, passport printing and portable small format printers.

Both liquid toner and solid toner colour laser are fast and compete with the larger scale commercial labs where high throughput is important. For both the prints are laminated with a polymeric film which can consist of polyester and other polymers and may contain UV absorbers to provide additional protection from light. Lamination can help to overcome problems such as differential.

For Wholesale photofinishing AgX and laser tend to dominate. Currently in the digital minilabs segment AgX systems dominate.

For home printing ink jet is the most commonly used output technology for printing digital photos. Ink jet is just starting to enter the minilab market. In all cases the most commonly used substrate tends to be the resin coated photopaper which is now used for most traditional AgX prints.

The whole area of digital photofinishing is developing fast and all the printing technologies will compete in this lucrative market segment.

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Biography

Aidan Lavery received his BSc(1980) and PhD(1984) in chemistry from Queen’s University Belfast. He carried out postdoctoral studies on transition metal chemistry at Edinburgh University before becoming a lecturer in Chemistry at Huddersfield University. In 1988 he joined ICI/Zeneca, where he spent 11 years. He became Group Leader for the Physical Science team developing ink jet systems. In 1999 he took up his current position with Felix Schoeller Imaging as Head of R&D for media development. His interests have included the development of ink jet formulations, the development of photomedia, and ink/media interactions.

Dr. Harald Siegers has worked for Felix-Schoeller for over 30 years and has been closely involved with the Photofinishing market throughout this time.