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DIGITAL ALKALI RESIST PRINTS ON POLYESTER

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Abstract

In earlier papers we have described sulphite-based and secondary amine-based resist printing of cotton using ink-jet procedures. This paper describes the chemical resist printing of polyester fabrics padded with disperse dyes to create a white image on a coloured background. Polyester grounds have been prepared by the pad-*dry 'dyeing' of polyester fabrics with alka*li clearable disperse dyes, such as a Dianix PC (DyStar) or a Dianix SF (DyStar) dye, and subsequently ink-jet printed with sodium carbonate based ink formulations to yield a white image on a solid ground following high temperature steaming and appropriate wash-off procedures. Coloured images have been achieved by a two-step process whereby the coloured ground fabric was initially printed with an alkali based ink and then over-printed in a second step with an illuminating ink formulation containing a alkali stable disperse dye, such as a Dianix AD (DyStar) or Serilene ADS (Yorkshire Chemicals).

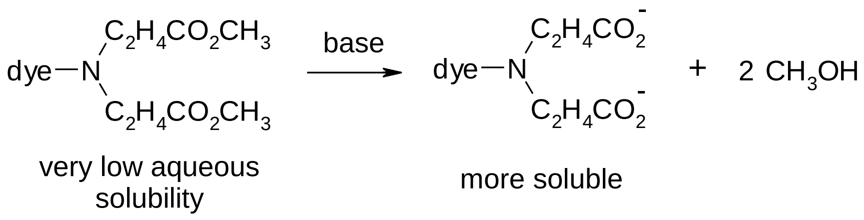
Introduction

Earlier papers [1-2] have described the ink-jet printing of white and illuminated resist effects on cotton substrates using either sodium sulphite or a secondary amine, such as N-methyltaurine, as the resist agent; sodium sulphite being used to create white resists on β-sulphatoethylsulphone grounds and N-methyltaurine being used to give white prints on monofluoro-s-triazine grounds. Illuminated images were prepared by the addition of a monohalo-s-triazine dye to the sodium sulphite based resist ink or a β-sulphatoethylsulphone dye to a N-methyltaurine based resist ink.

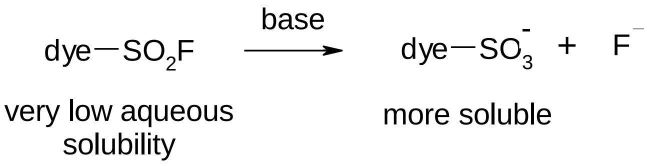
In this study we describe the use of alkali-based inks to inactivate an alkali clearable disperse dye and yield a modified dye that has no affinity for the polyester substrate and can thus be easily removed from the dyed fabric.

DyStar marketed the Dianix PC, formerly Dispersol PC (ICI), range of liquid disperse dyes, which were aimed at the production of ground dyeings on polyester for alkaline discharge/resist printing [3]. These dyes contained the ester groups of carboxylic acids which could be readily hydrolysed under alkaline conditions to produce a carboxylate dye that is water-soluble, scheme 1. Such dyes have no affinity for polyester fabrics and can be easily removed from the dyed fabric.

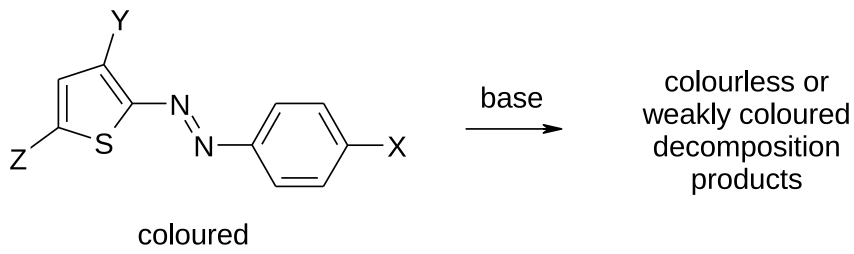
A second range of alkali hydrolysable disperse dyes marketed by DyStar were the Dianix SF, formerly Dispersol SF (ICI), range



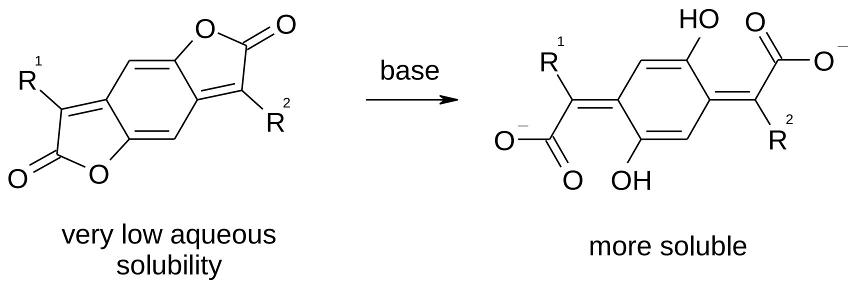
Scheme 1: The alkaline hydrolysis of a Dianix PC dye



Scheme 2**:** The alkaline hydrolysis of a Dianix SF dye



Scheme 3: The alkaline discharge of an azo thiophene type dye



Scheme 4: The alkaline discharge of a dibenzofuranone type dye

of disperse dyes that contained alkali hydrolysable sulphonyl fluoride groups. Under alkaline conditions, the sulphonyl fluoride groups are hydrolysed to sulphonic acid groups which in turn confers increased aqueous solubility on the product compared to that of the original dye [4], scheme 2.

In addition to the above chemistries, there were some disperse dyes, such as those based on azo thiophenes (scheme 3) which are destroyed to colourless by alkaline solutions or dibenzofuranones (scheme 4) in which the lactone rings are readily hydrolysed to yield a product of greater solubility than the original dye in aqueous alkali [5].

Thus, if a ground shade containing alkali-clearable disperse dyes is applied to polyester fabric and the fabric is dried at 80°C or below, then the dye at the surface can be readily resisted/discharged to colourless by printing with an ink or paste containing an aqueous alkali, such as sodium carbonate. Thermo-fixation at 170-210°C for 30-180 seconds and subsequent washing in an alkaline detergent bath yields a fabric exhibiting a white print on a coloured ground shade. If an alkali-resistant disperse dye is co-printed with the alkali solution and the fabric fixed as above, then a coloured design under a solid ground shade appears on washing-off. A coloured design may also be achieved in a two-step process in which the ground fabric is firstly printed with the alkaline ink formulation and secondly over-printed with an ink formulation containing an alkali stable disperse dye.

To exploit this chemistry in ink-jet printing resist/discharge styles the following procedures have been explored:

(1) Pad the polyester substrate with a pad liquor containing an alkali clearable disperse dye,
(2) Dry the fabric at 70-80°C,
(3) Print the ground shade with an ink formulation containing either an alkali (white image) or an alkali and a alkali stable disperse dye (coloured image),
(4) Promote the resist/discharge process by steaming,
(5) Fix the background by thermosol treatment,
(6) Soaping-off any unfixed materials in an alkaline detergent.

Experimental

Materials:

A lightweight bleached polyester fabric from Whaleys (Bradford, UK) was used throughout. Commercially available disperse dyes from various dye manufacturers were studied – they included the following:

Alkali clearable disperse dyes were selected from the Dianix PC range of dyes from DyStar (formally Dispersol PC dyes – ICI) which contain alkali hydrolysable ester groups), or the Dianix SF range of dyes from DyStar which contain alkali hydrolysable sulphonyl fluoride groups). Alkali stable disperse dyes were chosen from the Dianix AD range of dyes from DyStar, or the Serilene ADS range of dyes from Yorkshire Chemicals. All other chemicals were of laboratory grade as supplied by Aldrich Chemicals (UK).

Methods:

A desk-top HP 540 ink-jet printer was used to print all fabrics. Cartridges were cut open and filled with the necessary inks. The prepared resist/discharge ink formulations were filtered through a Whatman No 1 filter paper prior to their addition to the ink cartridge in order to remove any fine insoluble material that may have resulted in subsequent print head blockage problems.

In all cases, the prepared polyester ground fabrics (padded with an alkali clearable disperse dye and thickening agent) were dried at 70-80°C to yield a dry substrate that could be mounted on sheets of paper prior to the subsequent ink-jet printing processes. The prepared polyester ground fabrics mounted on A4 pieces of paper were ink-jet printed on a HP 540 ink-jet printer using an alkali based ink formulation. The printed fabrics were steamed at 104°C for 10 minutes on a Mathis laboratory steamer/baker unit to initiate the resist/discharge process and then baked at 200°C for 30 seconds to fix the ground dye. The prints were rinsed with cold water and soaped at 100°C for 15 minutes with an aqueous solution of Sandozin NIE (2 gdm^{-3}) and sodium carbonate (5 gdm^{-3}) to remove the water- soluble hydrolysed ground dye and yield white or paler images on a coloured ground.

Photographic quality prints were achieved by printing the negative image of a picture on a sepia coloured ground fabric. A coloured picture (positive image) was converted to a monochrome grey scale image on a PC and subsequently to a monochrome negative image of the original print. The negative image was printed on a sepia coloured ground fabrics using ink formulations containing sodium carbonate and polyethylene glycol.

Preparation of coloured ground fabrics

Coloured ground fabrics were prepared by padding polyester with dye liquors containing an alkali clearable disperse dye (Dianix PC or Dianix SF (DyStar), 10 - 40 gdm^{-3}), a thickening agent (Cellcosan 2000 (Noviant BV) (CHT), 8 - 40 gdm^{-3}), and a wetting agent (Sandozin NIE (Clariant), 3 gdm^{-3}); the pad liquor being adjusted to pH 4 via the addition of acetic acid so as to prevent the premature hydrolysis of the ground dye. Alternative thickeners that have been incorporated in the ground pad liquor include Meypro Gum (Rhodia), CHT Alginat MV (CHT), and CHT Alginat EHV (CHT).

Alkali clearable dyes employed during the following study for the ground shade were selected from the Dianix PC and Dianix SF ranges and include Dianix Yellow 7G PC liquid, Dianix Brilliant Orange GN PC liquid, Dianix Brilliant Red SF PC liquid, Dianix Red 4G PC liquid, Dianix Red BN PC liquid, Dianix Rubine 3B PC liquid, Dianix Blue R PC liquid, Dianix Navy 5R PC liquid, Dianix Navy G PC liquid, Dianix Brown 3G PC liquid, Dianix Black R PC liquid, Dianix Crimson SF, Dianix Brilliant Scarlet SF liquid and Dianix Deep Red SF.

Monochromatic photographic images were produced on sepia coloured grounds when printed with an alkali based ink. Such grounds were prepared using the following pad liquor:

10 gdm^{-3} Dianix Blue R PC liquid, 12 gdm^{-3} Dianix Yellow 7G PC liquid, 8 gdm^{-3} Dianix Brilliant Scarlet SF liquid, 8 gdm^{-3} Cellcosan 2000, adjusted to pH 4 with acetic acid.

The fabrics were padded on a Mathis laboratory padder set to give a wet pick-up of 100% and then dried at 70 - 80°C for 3 minutes in a Mathis laboratory drier to yield coloured ground fabrics for the subsequent resist/discharge printing process; the low temperature being employed to prevent premature fixation of the ground colour prior to ink-jet printing.

The printed fabrics were subjected to ISO 105-C06:2010C2S wash-fastness tests in which the printed sample and a multi-fibre adjacent fabric are treated at 60°C for 30 minutes in an aqueous solution containing ECE Reference Detergent without optical brightener (4 gdm^{-3}), sodium carbonate (1 gdm^{-3}) and sodium perborate tetrahydrate (1 gdm^{-3}). Each test tube had 25 steel balls added to it prior to running.

The wash tests were carried out using a James Heal Gyrowash wash-fastness tester.

The light-fastness of the prints was determined using a James Heal TruFade light-fastness tester according to the method described in ISO B02:2013.

The wet and dry rub-fastness of the prints were determined using a James Heal motorised Crockmaster rub-fastness tester in accordance with the method described in ISO 105-X12:2001.

The viscosities of the resist/discharge and illuminating inks were measured at 20°C, 60 RPM on a Brookfield DV-I+ viscometer using a low viscosity attachment, whilst the surface tensions of the inks were determined using a torsion balance (White Electric Instrument Company Ltd).

To determine the sharpness of the printed image a series of vertical lines of varying thickness were printed using the illuminating ink on the prepared substrate, the line widths varying from 40 to 400 µm in 40 µm steps. The printed images were fixed as previously described and the printed substrates finally washed-off as before. The widths of the printed lines were measured using a Lynx dynascope (Vision Engineering) connected to a GXCAM-3 digital camera (GT Vision Ltd).

Results and Discussion

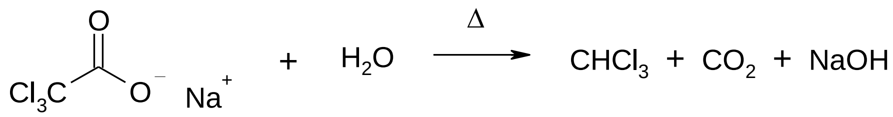
Thickening agents were included in the ground pad liquor to prevent migration of the alkali resist ink during subsequent printing operations, thus resulting in a loss of print quality (sharpness and definition) and the development of haloing effects. It was observed that thickener concentrations of at least 40 gdm^{-3} were required to ensure that no printing ink migration occurred. If lower concentrations of thickener were present, then some dyes gave sharp high quality prints, whilst in other cases significant ink migration occurred. The work reported here has focussed solely on the use of natural thickening agents due to their low cost and availability, however, future studies will focus on the use of synthetic thickening agents.

Ground fabrics padded with alkali clearable disperse dyes (pH 4) were stable to storage and have been used for subsequent resist/discharge printing up to 14 days after padding.

Ink preparation

Resist/discharge inks capable of producing white images on alkali clearable disperse dye padded ground fabrics may be formulated from alkalis such as sodium carbonate, sodium bicarbonate, sodium hydroxide, sodium formate, sodium acetate, ammonium hydroxide or substances such as sodium trichloroacetate that are capable of being decomposed by heat to generate an alkali. This process may be represented as shown in scheme 5.

Illuminated inks may be formulated by incorporation of an alkali stable disperse dye, such as a Serilene ADS (Yorkshire Chemicals) or Dianix AD (DyStar) dye, in the white discharge/resist ink formulation; such inks enabling the production of multi-coloured images on a coloured ground in a single step printing operation. Alternatively, multi-coloured images may be produced in a two-step process during which the coloured ground fabric is firstly printed with a white discharge/resist ink and secondly over-printed with an ink formulation containing a alkali stable disperse dye.



Scheme 5: Thermal decomposition of sodium trichloroacetate

White resist/discharge ink formulation

Inks capable of generating white images on coloured grounds were formulated in accordance with the following recipe: 100 gdm^{-3} alkali, 150 gdm^{-3} humectant, 20 gdm^{-3} 2-pyrrolidinone, 25 gdm^{-3} propan-2-ol, and made up to 1 litre with distilled water.

The alkalis employed in the ink formulations included sodium carbonate, sodium formate (pH 8), sodium hydroxide, trisodium phosphate and triethanolamine. Most alkalis employed produced ink formulations capable of producing white images on the coloured ground fabric; the inks being stable to storage at room temperature. However, trisodium phosphate based ink formulations containing polyethylene glycol (MW 300) were found to be unstable on storage, the alkali readily precipitating from solution overnight.

The choice of humectant present in the ink formulation was of considerable importance as some humectants were shown to produce ground colour resist/discharge more readily than others; thus giving rise to whiter print areas. The humectant is vital to the resist discharge process as it attracts moisture to the print area and so enables the hydrolysis reaction to operate successfully. The humectants employed included ethylene glycol, polyethylene glycol (MW 300), glycerol or N-methylmorpholine N-oxide (200 gdm^{-3}). However, ink formulations containing glycerol were found to be too viscous to ink-jet print successfully. Of the remaining humectants, ethylene glycol appeared to be the least suitable at drawing water to the print area and so produced final prints that were not fully resisted/discharged, whilst N-methylmorpholine N-oxide based ink formulations seemed to attract the highest water content. Thus, ink formulations incorporating N-methyl-morpholine N-oxide were found to cause bleeding and migration of the resist/discharge ink to the ground colour if insufficient thickening agent was incorporated in the ground pad liquor.

Propan-2-ol was added to the ink to change its surface tension and ensure that its physical properties were suitable for printing through the HP print head employed. The addition of propan-2-ol resulted in a lowering of the surface tension of the inks from 40-45 $dynes.cm^{-1}$ to 31-33 $dynes.cm^{-1}$. 2-Pyrrolidinone was added to the ink formulation as an additional solubility enhancer.

The best white resist/discharge prints were obtained on Dianix PC padded ground fabrics printed with ink formulations containing sodium carbonate (100 gdm^{-3}) and polyethylene glycol (MW 300) (150 gdm^{-3}). The resist/discharge ink produced had a surface tension of 33.0 $dynes.cm^{-1}$ and a viscosity of 3.38 cP. The printed fabrics were steamed at 104°C for 10 minutes to initiate the resist/discharge process and baked at 200°C for 30 seconds to fix the ground dye. Prints exhibiting a white image on a colour ground were achieved. Print sharpness and quality were found to be dependent on the quantity of thickener present in the ground pad liquor; a thickener concentration of 40 gdm^{-3} enabling prints of high quality to be achieved.

The above process was repeated, but in this case the printed fabrics were steamed at 120°C for 10 minutes prior to baking. In this case, the resist/discharge process was not as efficient as previously observed and printed areas that were not totally resisted/discharged were obtained. Thus, printed areas of lighter colour were achieved rather than the desired white image. This indicates that steam offering a high moisture content must be employed if adequate ground dye resist/discharge is to be achieved.

Coloured ground fabrics printed with resist/discharge inks containing sodium hydroxide and ethylene glycol produced prints offering varying degrees of whiteness; the results not being as good as those achieved when using sodium carbonate and polyethylene glycol.

Resist/discharge prints were also achieved on coloured grounds printed with inks containing triethanolamine and polyethylene glycol. Again prints offering different degrees of resist/discharge were achieved depending on the ground dye employed; Dianix Blue R exhibiting white print areas, whilst Dianix Yellow 7G showed virtually no ground dye resist/discharge at all.

Coloured ground fabrics printed with inks containing ethylene glycol and sodium formate (pH 8) yielded subsequent prints that demonstrated some ground dye resist/discharge had taken place; the printed areas being a pale ground colour and not white.

Coloured ground fabrics were printed with inks containing sodium carbonate and ethylene glycol, and the prints developed by baking at 220°C for 30 seconds. The prints were rinsed with water and soaped with an alkaline solution of Sandozin NIE as before to yield light coloured images on a coloured ground; the image areas exhibiting a pale ground colour rather than the required white image.

In all cases, subsequent prints demonstrating excellent wash-fastness properties were achieved after suitable soap-off procedures had been carried out.

Monochrome photographic images on sepia grounds

Sepia prints demonstrating photographic quality images of excellent wash-fastness were achieved. It was observed that on tone resist/discharge of the trichromatic ground colour had not taken place. Thus, further ground dye selection was required to produce a trichromatic sepia ground in which all three separate dye components could be removed equally (i.e. same percentage of each dye component being removed) and so yield a photographic quality image exhibiting on tone resist/discharge.

Illuminated resist/discharge formulations

As yet no resist/discharge inks containing an alkali stable disperse dye have been formulated. However, multi-coloured images have been produced on a coloured ground fabric using a two-step process that involves initially printing the coloured ground with a white resist/discharge ink and then over-printing in a second step with an ink containing an alkali stable disperse dye.

Illuminating inks for two-step printing processes

Multi-coloured prints were achieved on solid grounds using a two-step process in which the ground fabric was initially printed with a resist/discharge agent and then over-printed in a second step with inks incorporating alkali stable red, yellow or blue illuminating dyes. The alkali stable illuminating inks were formulated in accordance with the following recipes:

Recipe 1 - 50 gdm^{-3} alkali stable disperse dye, 100 gdm^{-3} Disperby K-190 (BYK Chemie), 20 gdm^{-3} 2-pyrrolidinone, 25 gdm^{-3} propan-2-ol, 150 gdm^{-3} ethylene glycol, and made up to 1 litre with distilled water.

Recipe 2 - 100 gdm^{-3} Dianix AD dye, 100 gdm^{-3} Disperby K-190 (BYK Chemie), 20 gdm^{-3} 2-pyrrolidinone, 25 gdm^{-3} propan-2-ol, 200 gdm^{-3} N-methylmorpholine N-oxide, and made up to 1 litre with distilled water.

The dyes employed in recipe 1 were Dispersol Red 2B (CI Disperse Red 60 (DyStar)), Foron Yellow E-RGFL (CI Disperse Yellow 23 (Clariant)) and Foron Blue S-BGL (CI Disperse Blue 73 (Clariant)). The inks were milled on an Eiger mill for 1 hour prior to use. The dyes employed in recipe 2 were Dianix Red AD-2B, Dianix Blue AD-R and Dianix Yellow AD-G. The inks were stirred at room temperature, but not milled.

The illuminating inks produced according to recipe 1 had a surface tension of 31.0 $dynes.cm^{-1}$ and a viscosity of 1.89 cP. The inks formulated according to recipe 1 were stable for 1-2 days, after which time cartridge blocking occurred. However, the dyes formulated according to recipe 2 could be printed for up to 14 days without any evidence of cartridge blocking.

Previously prepared ground shades were ink-jet printed with a white resist ink containing sodium carbonate and polyethylene glycol, and then over-printed with a tri-colour ink cartridge containing a red, yellow and blue alkali stable disperse dye based illuminating inks. The twice printed fabrics were steamed, baked and soaped-off as before to yield prints exhibiting multi-coloured images on solid ground shades. Further prints were prepared as above, but in this case the ground dye was resisted/discharged with an ink formulation containing sodium carbonate and N-methylmorpholine N-oxide (200 gdm^{-3}). Prints exhibiting multi-coloured images on a coloured ground were again achieved.

In all cases, prints demonstrating excellent wash-fastness properties were achieved after suitable soap-off procedures had been carried out. The final prints exhibited a Grey Scale colour change rating of 5 for the ground shade and the resist images when subjected to the ISO 105-C06:2010C2S wash-fastness test; the adjacent multi-fibre strip exhibiting a Grey Scale staining rating of 5 for all the adjacent textile substrates.

The prints obtained exhibited excellent dry and wet rub-fastness properties, the prints obtained exhibiting Grey Scale ratings of 5 for both the wet and dry rub-fastness tests for both the ground shade and the digitally printed illuminating images.

The printed samples exhibited excellent light-fastness results for both the both the ground shade and the digitally printed illuminating images, all the samples exhibiting a Blue Wool rating of at least 6.

A two-step process appeared most suitable for the production of coloured photographic quality images on a solid coloured ground, as it enabled a white background area to be achieved for the illuminated print. This is desirable as it allows for non-coloured areas in the print to be white (such areas would remain ground coloured in a single-step process unless specifically printed with a cartridge containing the white resist/discharge ink) and also provide a suitable background for lighter coloured areas of the print (the ground of such areas may not be totally resisted/discharged when printing with an illuminated resist ink in a single-step process).

The process is best illustrated using selected photographs of the prints produced (Figures 1-4):

Sample 1 shown in Figure 1 was prepared:

Step 1: Pre-pad ground shade with 10 gdm^{-3} Dianix Yellow 7G PC liquid plus 8 gdm^{-3} Cellcosan 2000 and dry.

Step 2: Ink-jet print with resist ink containing 100 gdm^{-3} sodium carbonate plus 150 gdm^{-3} ethylene glycol, steam, thermosol and wash-off.

Figure 1: White resist/discharge on single shade ground.

Sample 2 shown in Figure 2 was prepared:

Step 1: Pre-pad ground shade with 12 gdm^{-3} Dianix Yellow 7G PC liquid, 5 gdm^{-3} Dianix Blue R PC liquid, 8 gdm^{-3} Dianix Red 4G PC liquid plus 8 gdm^{-3} Cellcosan 2000 and dry.

Step 2: Ink-jet print with resist ink containing 100 gdm^{-3} sodium carbonate plus 150 gdm^{-3} Polyethylene glycol MW 300, steam, thermosol and wash-off.

Figure 2: Monochrome photographic print on trichromatic ground shade.

Sample 3 (illuminated resist/discharge) shown in Figure 3 was prepared:

Step 1: Pre-pad ground shade with 12 gdm^{-3} Dianix Yellow 7G PC liquid, 10 gdm^{-3} Dianix Blue R PC liquid, 8 gdm^{-3} Dianix Brilliant Scarlet SF liquid plus 8 gdm^{-3} Cellcosan 2000 and dry.
Step 2: Ink-jet print with resist ink containing 100 gdm^{-3} sodium carbonate plus 150 gdm^{-3} Polyethylene glycol MW 300.

Step 3: Ink-jet print with illuminating inks containing 50 gdm^{-3} Foron Yellow E-RGFL, or 50 gdm^{-3} Foron Blue S-BGL, or 50 gdm^{-3}

Dispersol Red 2B, steam, thermosol and wash-off.

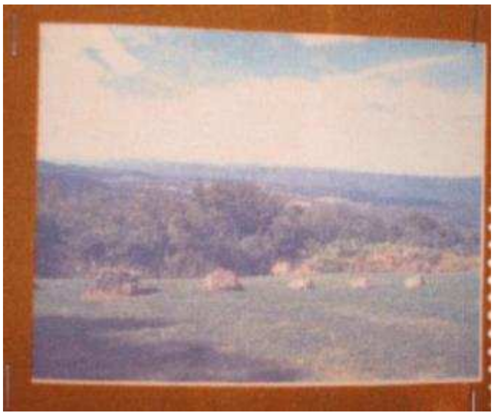


Figure 3: Illuminated resist on a trichromatic sepia ground shade via two-step process.

Sample 4 (illuminated resist/discharge) shown in Figure 4 was prepared:

Step 1: Pre-pad ground shade with 10 gdm^{-3} Dianix Yellow 7G PC liquid, plus 40 gdm^{-3} CHT Alginat MV and dry.

Step 2: Ink-jet print with resist ink containing 100 gdm^{-3} sodium carbonate plus 200 gdm^{-3} N-Methylmorpholine N-oxide.

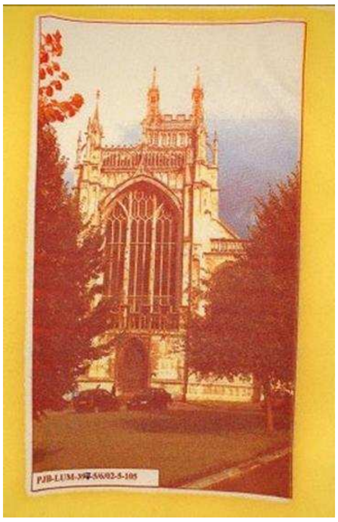


Figure 4: Illuminated resist on a single hue ground shade via two-step process

Step 3: Ink-jet print with illuminating inks containing 100 gdm^{-3} Dianix Red AD-2B, or 100 gdm^{-3} Dianix Blue AD-R, or 100 gdm^{-3} Dianix Yellow AD-G, steam, thermosol and wash-off.

Line quality analysis

Tse et al [6] used line quality analysis as a way to determine the print quality of digitally printed images on textile substrates. The line width gain of the printed image compared to the requested line width was used as a measure to evaluate the sharpness of the printed image. The printed line width and percentage line width gain is represented graphically in figures 5 and 6. Figure 5 indicates that in all cases the actual line width obtained is greater than the actual line width requested, the percentage increase in the actual line width obtained decreasing with increasing requested line width being printed.

CONCLUSIONS

Dianix PC dyes (DyStar) are range of alkali clearable disperse dyes which contain carboxylate ester groups that can be readily hydrolysed under alkaline conditions to water soluble carboxylate groups. Such dyes have no affinity for polyester and so can be readily removed from such fibres. A related group of dyes that can also be removed under alkaline conditions is the Dianix SF range (DyStar). Such dyes can be padded on polyester fabrics at pH 4 to provide coloured ground fabrics that can be subsequently ink-jet printed with suitable resist/discharge inks to yield white images on a coloured ground. The pad liquors should contain a suitable viscosity modifier (40 gdm^{-3}), such as an alginate (CHT Alginat MV)

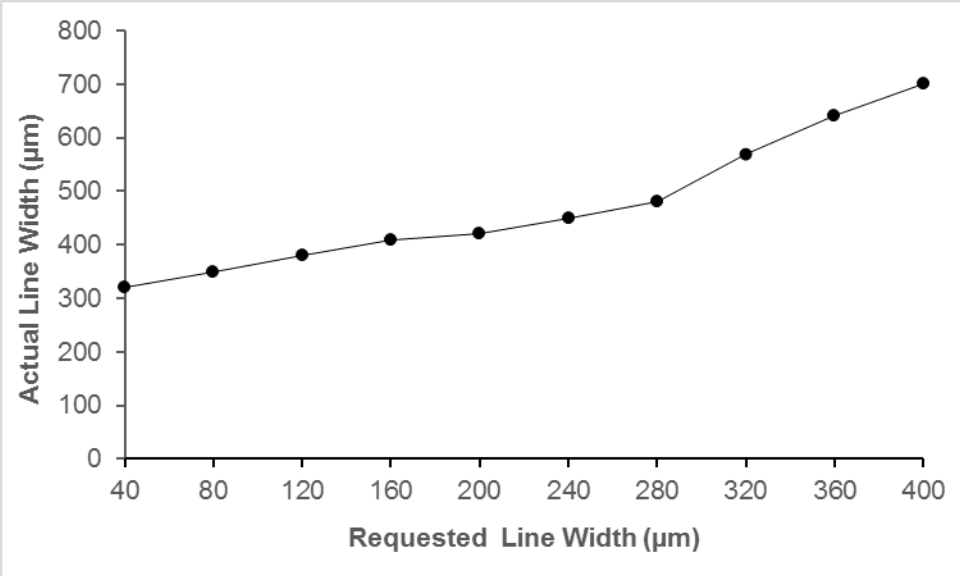


Figure 5: Actual line width obtain compared to the requested line width printed

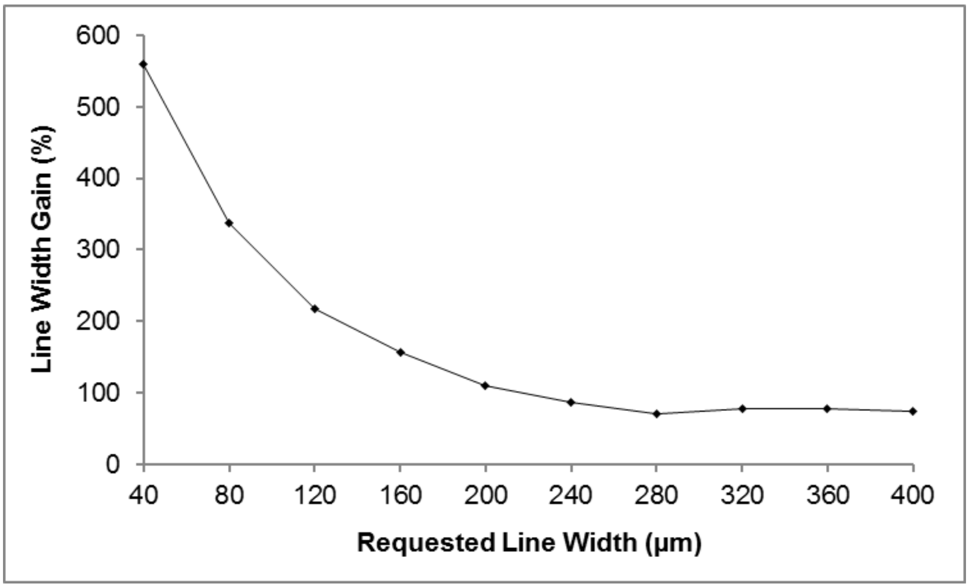


Figure 6: Percentage line width gain compared to the requested line width

or carboxymethylcellulose (Cellcosan 2000) thickener, to enable subsequent prints of high clarity and sharpness to be produced. The fabrics once padded are stable to storage and may be held for several weeks prior to alkali printing.

White image areas can be achieved on suitably prepared grounds using resist/discharge inks that incorporate an alkaline dye inactivating species. Such inks can be formulated from sodium carbonate, sodium hydroxide or triethanolamine. The inks must contain a humectant, such as polyethylene glycol or N-methylmorpholine N-oxide to enable adequate hydrolysis of the ground dye to occur during the steaming phase. In particular, white images may be prepared on Dianix PC padded fabrics by ink-jet printing the ground fabric with an ink formulation containing sodium carbonate and polyethylene glycol, steaming the fabric at 104°C for 10 minutes to hydrolyse the ground dye, baking the printed fabric at 200°C for 30 seconds to fix the ground dye and finally soaping the in an alkaline detergent solution at 100°C to remove the unfixed hydrolysed ground dye.

Photographic quality images can be produced on sepia coloured ground fabrics ink-jet printed with sodium carbonate and polyethylene glycol based ink formulations; the prints exhibiting images of high definition, clarity and sharpness. However, the sepia ground fabrics employed so far have not resulted in on-tone resist/discharge and so further dye combinations would have to be established to bring about this effect.

Multi-coloured images can be prepared on coloured ground fabrics in a two-step process, whereby the ground fabric is printed with an alkali containing resist/discharge ink and then over-printed in a second step with an illuminating ink containing an alkali stable disperse dye. Such inks may be formulated using the Dianix AD or Serilene ADS ranges of alkali stable dyes. The prints are developed as for the white resist/discharge images to yield multi-coloured images on a coloured ground. A two-step process provides a suitable method to produce coloured photographic quality prints on coloured ground shades since it enables the complete inactivation of the ground dye in the illuminated print area to be achieved. This is advantageous as it enables non-coloured areas of the print to remain white (in a single-step process such areas would have to be printed with an alkali based formulation) and also enables total ground dye deactivation in print areas of low colour yield (in such areas, less colour would be printed down and so there may be insufficient alkali available to totally deactivate the ground dye if using a single step process).

The white or multi-coloured prints obtained on the coloured ground fabrics exhibited excellent wash-fastness properties after they had been thoroughly soaped in an alkaline detergent solution to remove any inactivated hydrolysed ground dye.

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