A comparative study on the behaviour of coated and inkjet printed photo-responsive textiles for conventional and high-tech applications

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ABSTRACT

A comparative study was carried out on the behaviour of coated and inkjet printed photo-responsive textiles and their behaviours were rigorously analysed to study the feasibilities relating to their applications (both conventional and high-tech applications). During this study coating formulations were optimised and a range of photochromic dyes (such as, spirooxazines, spiropyrans, naphthopyrans, diarylethenes) were used in the coating formulations and applied on different textile substrates and their photochromic colour changing performances on exposure to UV light or sun light were evaluated. Similarly, the same range of photochromic dyes were used in the inkjet ink formulations and the behaviour of the inks and the inkjet printed textiles were evaluated. Inkjet printing technology, a modern non-impact printing technique, is making its own way of revolutionising the whole printing industry, including textile printing, for producing almost any print design on textiles within a very short time providing this technique a cutting edge over other conventional printing techniques. Both the photo-responsive inkjet printed textiles and coated photo-responsive textiles have many applications, some of which include, fashion and design, self-indicating alert systems, anti-counterfeit, security and brand protection. Both photochromic dispersed and photochromic acid dyes can be used to formulate inkjet inks to produce photo-responsive inks for inkjet printing on different types of textiles (for example, cotton, wool, silk, nylon) for potential conventional and high-technology applications. Formulation of inkjet inks using functional dyes, such as, photochromic dyes needs proper care for producing jettable inks which can retain functional behaviour for a considerable period along with other desired properties (for instance, high print quality and robust technical performances of printed textiles). In addition, the porosity of the substrate plays a significant role on the absorption or penetration behaviour of an inkjet ink or more simply regulates its spreading on a substrate thus controlling inkjet printed image quality and the technical performances of an ink to some extent. As a result, it is necessary to control a number of influencing factors to produce desired high quality printed responsive substrates with good technical performances for various applications. This paper briefly states some of these issues along with the applications of inkjet printed photo-responsive textiles and coated photo-responsive textiles for a variety of conventional and high-tech applications.
Keywords: Photo-responsive, coated or inkjet printed textiles, conventional and high-tech applications.

INTRODUCTION

Photo-responsive materials (such as, photochromic dyes) were used to formulate coating formulations and inkjet inks to produce stimuli-responsive coated and inkjet printed textiles (such as, cotton, polyester, wool, silk, nylon). Both the coated and inkjet printed textiles were responsive to UV light or sun light. The technical performances (such as, light fastness and washfastness) of the coated and inkjet printed photochromic textiles were evaluated using specifically developed methodologies. Some of the coated and printed textiles showed very high technical performances which made them suitable for various potential applications, including, self-indicative UV alert system, adaptive and active camouflage, fashion and design, protective security systems. This current paper briefly illustrates different characteristic features of stimuli-responsive materials based coated and printed textiles and their applications.

EXPERIMENTAL

For this current study, a spirooxazine (6'-sulfonato-1,3,3-trimethyl spiroindolinonaphth[2,1-b][1,4]oxazine-monosodium salt hydrate), three diarylethenes (cis-1,2-dicyano-1,2-bis(2,4,5-trimethyl-3-thienyl)ethane or CTME; 1,2-bis(2,4-dimethyl-2,4-dimethyl-5-phenyl-3-thienyl)-3,3,4,4,5,5-hexafluoro-1-cyclopentane or 6FDA; 2,3-bis(2,4,5-trimethyl-3-thienyl)malimide or bismid), a naphthopyran (3,3-diphenyl-*3H*-naphtho[2,1-b]pyran) and a spiropyran (1'-(2-hydroxyethyl)-3',3'-dimethyl-6-nitrospiro[1(*2H*)-benzopyran-2,2'-indoline]) were used as photochromic molecular switches for the formulation of inkjet inks and coating compositions. Inkjet inks were formulated (using modified formulation techniques typically used for aqueous and solvent based inkjet ink formulations) and images were printed using a piezoelectric printhead (e.g. Xaar Omnidot 760) to print identical solid block patterns on flexible polymeric substrates (such as, cotton, polyester, nylon, silk and wool). After coating and printing the printed substrates were then dried in the air. For assessment, the coated and inkjet printed substrates were irradiated using UV light (365 nm, maximum wavelength) for specific times and the photochromic switching behaviour was evaluated in terms of the colour build-up assessed using reflectance spectroscopy, by measuring the reflectance which was then converted to the K/S (the ratio of the co-efficient of absorption and the co-efficient of scatter) value. Colour differences (ΔE) before and after UV irradiation were also measured. In addition, 3,3,5,6-tetramethyl-1-propylspiro [indoline-2,3'[3H] pyrido [3,2-f][1,4]benzoxazine] or D1; 1,3,3,5,6 - pentamethyl(indoline - 2,3’ -[3H] naphtho [2,1 - b] [1,4] oxazine]) or D2; methyl 2,2,6-tris(4-methoxyphenyl)-9- methoxy-2*H*-naphtho-[1,2-*b*]pyran-5-carboxylate or D3; methyl 2,2-bis(4- methoxyphenyl)-6-acetoxy-2H-naphtho-[1,2-b]pyran-5-carboxylate or D4 and 3,3-diphenyl-3*H*-naphtho[2,1-*b*]pyran or D5 are also used for coating and inkjet printing of different textiles. Detail methods and methods of evaluation are described in previous communications. [1-3]

RESULTS AND DISCUSSION

Fig. 1(a) indicates the behaviour of cotton inkjet printed with a spirooxazine based inkjet ink where a specific soild block was printed on cotton for one (termed as 1X) to 10 times (termed as 10X) for specific time(s). The colour differences of the inkjet printed cottons (1X printed cotton to 10X printed cotton) from the unprinted cotton is illustrated in Fig. 1(a). It shows a significant level of increase in the background colour of the printed solid block on cotton obtained after inkjet printing for 10 times of the same solid block one over the other. To produce a jettable inkjet ink suitable for a microdisposal from a drop on demand piezoelectric print head to a terget textile substrate (such as, cotton) we had to modify the ink formulation using a variety of rheological modifiers and additives for particular purposes. When printed on different textile substrates they produce a very pale colour (sometime no colour at all was observed depending on the nature of the ink additives) due to a number of reasons, including, the impact of matrix on photochromic dye molecule which caused the development of a background colour to some extent as we see in Fig 1(a). Fig. 1(b) indicates that there is a different level of photochromic colour build up (after UV irradiation for 1 min) and fading behaviour (after removal from UV irradiation) from the solid blocks printed on cotton for specific times (one time, 1X to ten times, 10X). It also shows that photochromic colour build up from the 10X sample is much higher than the photochromic colour build up on the 1X printed sample to establish the fact that photochromic colour build up is a function of concentration of dye in the sample. Fig. 1(d) demonstrates a medium to intense level of blue colour build up on spirooxazine based inkjet ink printed cotton (10X) (in terms of K/S from before and after exposure to UV irradiation) from a nearly clourless state depending to the time of UV irradiation which reaches at the highest level after continuous UV irradiation for 60 seconds. This proves that photochromic colour build up is also a function of UV irradiation time. Fig 1(e) shows the photochromic yellow colour build up after UV irradiation when printed with naphthopyran based ink and reddish purple colour build up when printed with spiropyran based inks. Fig. 1(f) indicates different level of photochromic colour build up (yellow, reddish-purple and purple) from three different diarylethenes based inkjet printed substrates after UV irrdiation.

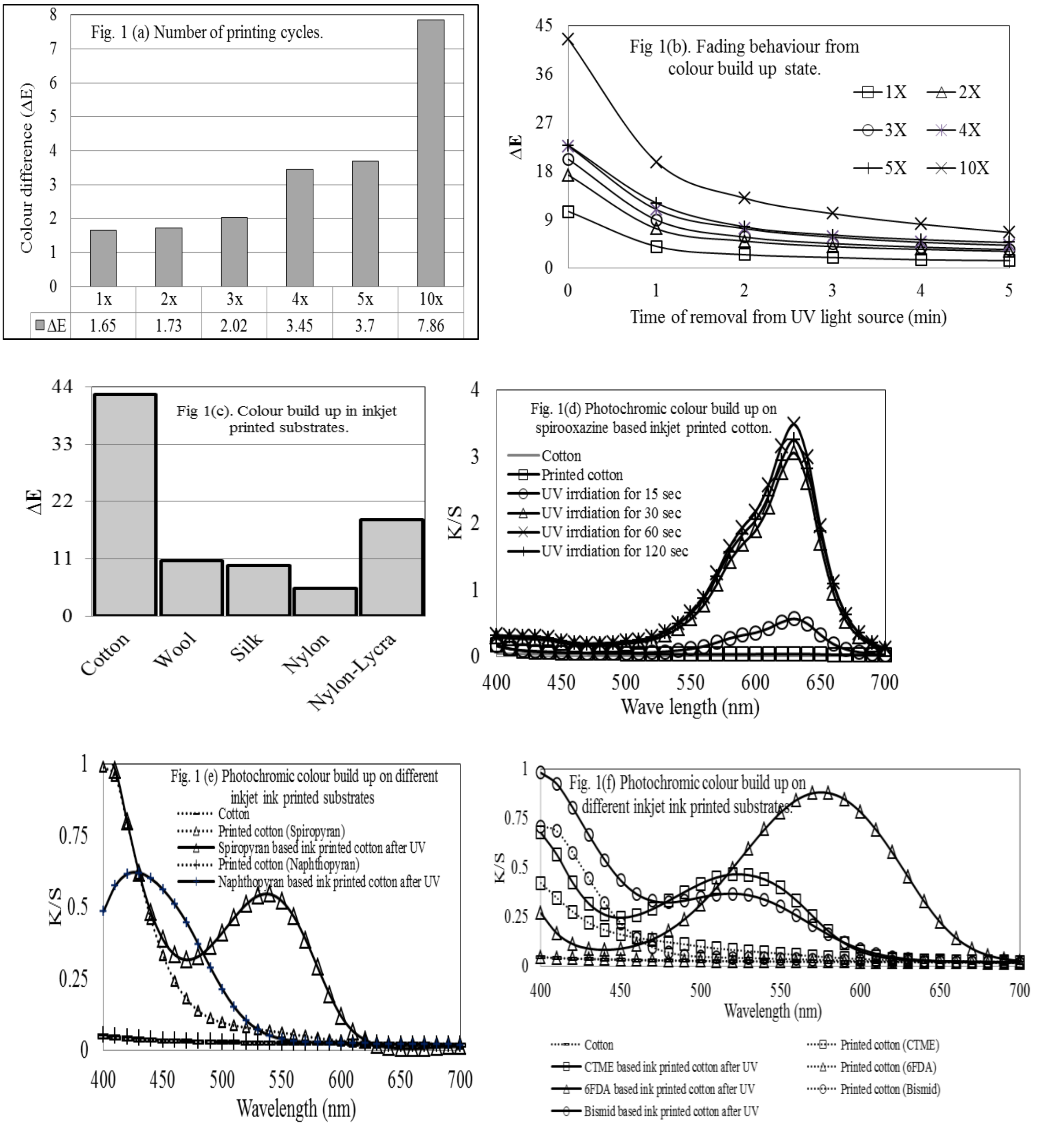

Fig 1. Photochromic behaviour of inkjet printed photochromic textile substrates.

Figures 2 to 4 illustrate the photochromic colour build up and fading behaviour of D1 to D4 coated polyester fabrics. Figure 4 demonstrates a comparative study on the photochromic colour build up on polyester fabric coated with D1-D5 based similar type of coating compositions. In addition, Figure 5 demonstrates a comparative study on the photochromic colour build up on polyester fabric coated with a D1based coating composition and inkjet ink based on D1 in both case just 1X is used. Figure 5 shows a comparative study on the photochromic colour build up on polyester fabric coated with a D1based coating composition and inkjet ink based on D1.

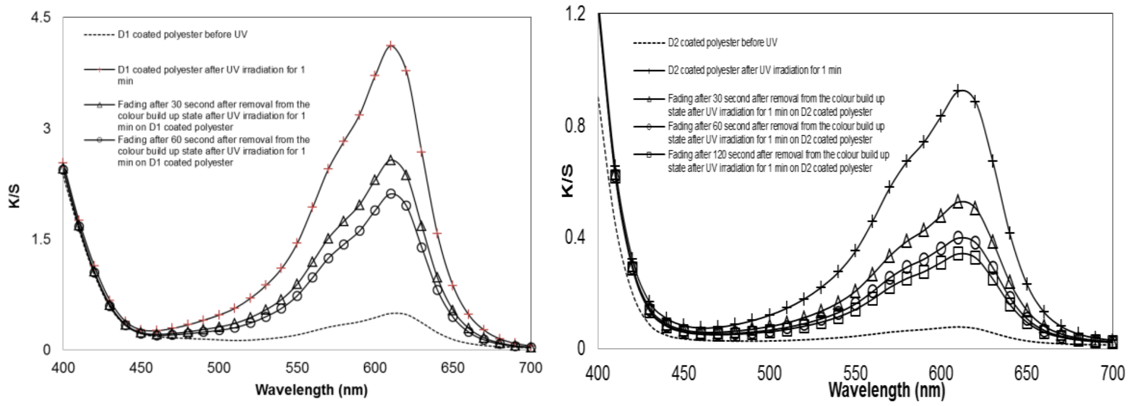

Fig. 2 Photochromic colour build up and fading behaviour of D1 coated polyester (left side) and D2 coated polyester (right side) fabrics.

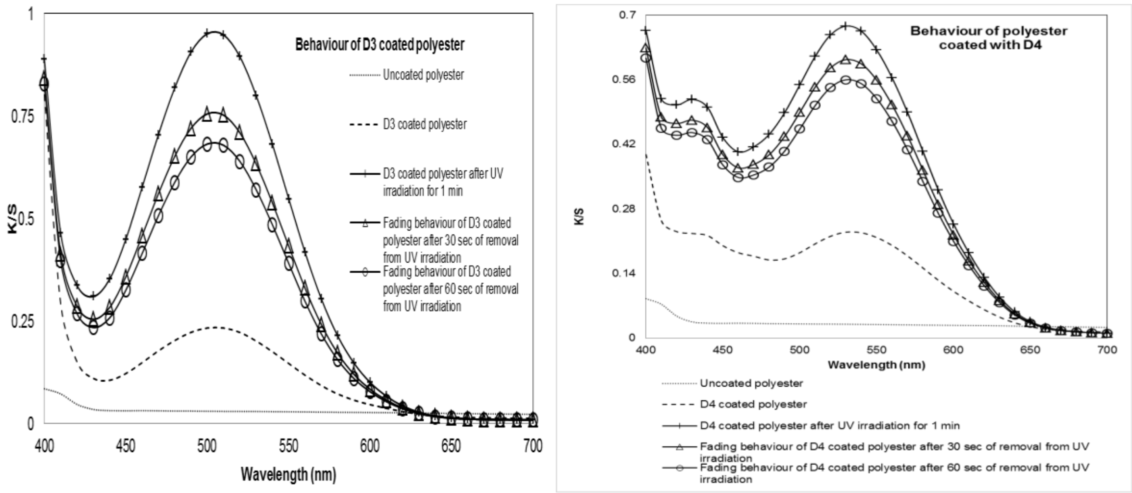

Fig. 3 Photochromic colour build up and fading behaviour of D3 and D4 coated polyester fabrics.

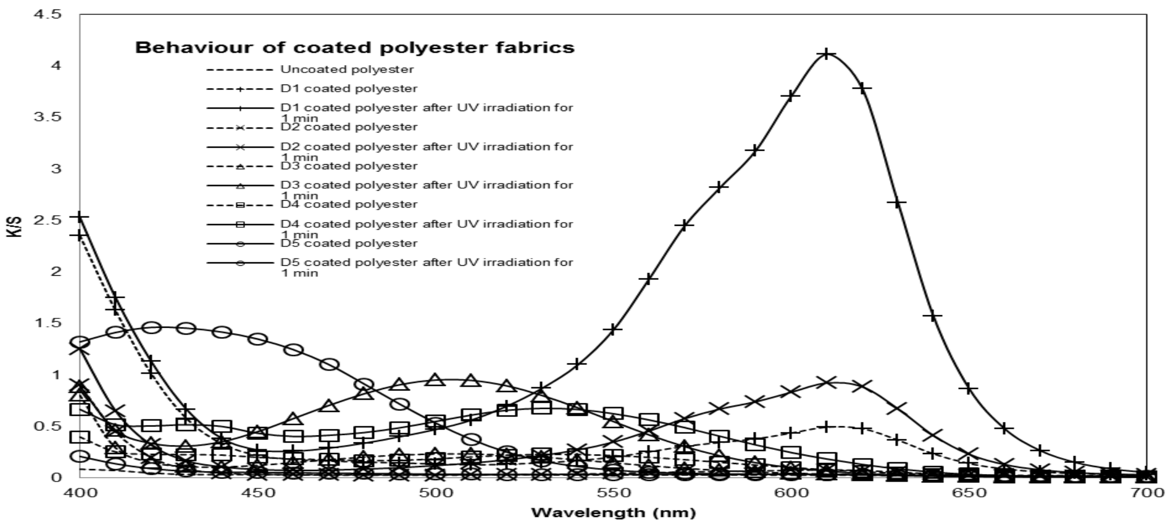

Fig. 4 Comparative studies on the photochromic colour build up on polyester fabric coated with D1-D5 based coating compositions.

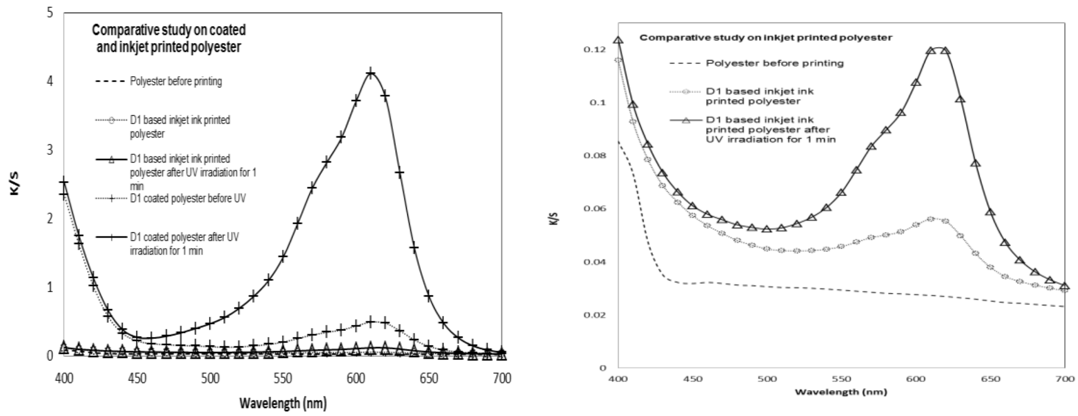

Fig. 5 Comparative studies on the photochromic colour build up on polyester fabric coated with a D1based coating composition and inkjet ink based on D1.

All of the inkjet printed and coated substrates, as shown in this current paper, showed this photochromic colour build up for a considerable period and different level of technical performances depending on the nature of the dye molecules, matrix and surrounding environments. [2] This reversible colour change from coated and inkjet printed stimuli-responsive surfaces have the potential for many applications.

Conventional and high-tech applications of coated and inkjet printed photochromic textiles

A good quality photochromic coated or inkjet printed textile show photochromic colour change for a long time and show a substantial retention of its reversible photochromic colour change behaviour even after exposed to different environmental conditions. This behaviour make it suitable for many potential applications, including in security, responsive surface, brand protection, authentication, actinometry, self-indicating UV warning system, active and adaptive camouflage, environmental warning system, electrophoretic textile based display, interior design, exterior design and also in fashion and design applications. In addition, coated or printed photochromic textiles have the potential for healthcare applications as well. The possibility to bind a photochromic molecule onto a naturally occurring receptors and enzymes which in turn bind with a coated or printed photochromic textile using certain techniques provides the opportunity to photo-regulate their binding and catalytic activities. In future, this type of photo-responsive textiles may be used for different therapy, bio-sensing and also in wound care along with their other applications. [2-4]

CONCLUSION

Photo-responsive colour build up on coated and inkjet printed substrates depends on a variety of factors, including the nature of the photochromic molecular switch (such as, the photochromic dyes), nature of the substrates and the surrounding environments. This study reveals that coated and printed photo-responsive textile surfaces produced by printing with inkjet inks or with coating formulations have a variety of potentials. There are quite a lot of challenges to produce stable, jettable and high quality inkjet inks using molecular switches to retain their switching behaviour for a long time for practical industrial applications which is also similar to the case of formulating high-quality coating formulations; which will be discussed in future publications.

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