Reprint ISSN 2076-3972 (Web Version)

Institutional Engineering and Technology (IET)

(*Inst. Engg. Tech.*)

Volume: 2 Issue: 2 August 2012

Inst. Engg. Tech. 2(2):21-27(August 2012)

AN INTERDISCIPLINARY APPROACH TO SMART TEXTILE DESIGN USING THERMOCHROMIC, PHOTOCHROMIC & CONVENTIONAL PIGMENTS

M.A. CHOWDHURY, B.S. BUTOLA AND M. JOSHI

GGF
Nature is Power

An International Scientific Research Publisher
Green Global Foundation©
Publication and Bibliography Division
100 Leeward Glenway
Apartment # 1601
M3c2z1, Toronto, Canada
E-mails: publication@ggfagro.com, editor@ggfagro.com
http://ggfagro.com/ejournals/current issues

IET** issn 2076-3972, HQ:19-10 cantral place, saskatoon, saskatchewan, s7n 2s2, Canada

ISSN-2076-3972 (Online)
Inst. Engg. Tech. 2(2):21-27(August 2012)

AN INTERDISCIPLINARY APPROACH TO SMART TEXTILE DESIGN USING THERMOCHROMIC, PHOTOCHROMIC & CONVENTIONAL PIGMENTS

M.A. CHOWDHURY, B.S. BUTOLA AND M. JOSHI

Department of Textile Technology, Indian Institute of Technology Delhi, India 110016.

Corresponding author & address: Muksit Ahamed Chowdhury, E-mail: muksit.iitd@gmail.com
Accepted for publication on 12 July 2012

ABSTRACT

Chowdhury MA, Butola BS, Joshi M (2012) An interdisciplinary approach to smart textile design using thermochromic, photochromic & conventional pigments. *Ins. Engg. Tech.* 2(2), 21-27.

Commercial photochromic and thermochromic colorants that change rapidly and reversibly from colorless to colored state when activated by surrounding environment like ultraviolet irradiation, temperature or pH offer significant potential for aesthetic and functional textile design in the area of smart materials. This paper presents an intelligent approach for producing “smart” design on textile fabrics using stimuli sensitive colorants like thermochromic and photochromic colorants together with conventional pigments by dyeing or printing in single step. Color measurements of the dyed samples were carried out considering their dynamic color changing properties and represented by reflectance curve. Wash fastness was measured by measuring color strength (K/S) and color difference (ΔE) of the samples after repeated washing and found good. A comparative study on the color build up on the test sample before and after exposure to the Xenon lamp after a specific time interval was used as a measure of light fastness behavior and found satisfactory. This paper represents a user friendly procedure to applying thermochromic, photochromic and non-thermochromic colorants on textile goods with best possible colorimetric properties.

Key words: *thermochromic colorants, photochromic colorants, pigments, smart design, wash fastness, light fastness*

INTRODUCTION

At the intersection of science, technology, materials and fashion, new multi-disciplinary partnerships are emerging as the basis for novel research of smart textile. There are considerable prospective for functional textile applications of thermochromism and photochromism in the field of ‘smart’ fabrics and clothing, which are engineered to sense and respond to external environmental conditions and stimuli. Color-changing textile would allow people to dynamically change the aesthetics of their clothing to suit their mood, their style, etc, allowing them to be creative and expressive in many ways (Christie *et al.* 2007).

Thermochromism has been defined as the reversible dependence of color on temperature and is described by:

Fig.1. Reversible change in color from species A to species B

Where A is a coloured or colourless species and B is another different colorless or colored species. Thus the thermochromic dyes changes shade reversibly with a relatively small change in temperature (Aitken *et al.* 1996). The temperature at which thermochromic colorants transfer from color to colorless state is known as activation temperature, T_c. The reversible thermochromic colorants are encapsulated; including colorless dye precursor, non-volatile organic solvent and a color developer. On heating, the organic solvent melts, which leads either to color development or color loss. On cooling, the solvent solidifies and the system reverts to its original color (Kulcar *et al.* 2011).

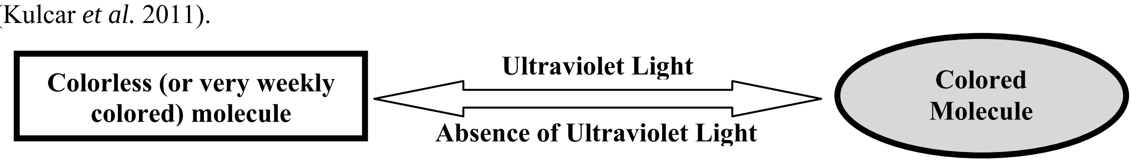

Fig. 2. Behavior of commercially important photochromic dyes

The phenomenon of photochromism may be defined as a reversible color change induced in a compound driven in one or both directions by the action of electromagnetic radiation. Many photochromic materials change color upon irradiation with ultraviolet (UV) or visible light and then revert back to their original color following removal of the illuminant. This is known as T-type photochromism when the back reaction is driven thermally. If the photochromic material only returns to its original state through irradiation with light of another range of wavelengths, i.e. the change is photochemically driven, then it is said to exhibit P-type photochromism. Most of the dyes used in industry show thermally driven back reaction i.e. T-type photochromism (Dawson 2010).

MATERIALS AND METHODS

Materials

The fabrics used were scoured, bleached cotton plane weave woven fabric containing no fluorescent brightening agent. A series of commercial thermochromic and photochromic colorants were used as given in Table 1, supplied by Americos Industries Inc., Gujarat, India. Non-thermochromic pigments were supplied by Pidilite Pigments, India.

Table 1. Commercial Thermochromic, Photochromic & Non-thermochromic conventional Pigments

Thermochromic Colorants	Photochromic Colorants	Non-thermochromic Pigments
Americos Thermochromic Red	Americos Photochromic Red	Texcron Yellow 5G/Sc
Americos Thermochromic Blue	Americos Photochromic Blue	Texcron Blue 3R/Sc

Printing

The samples were printed by thermochromic colorants, combination of thermochromic and non-thermochromic pigment and photochromatic colorants using the following recipe by screen printing method.

Recipe:For 100 parts

Thermochromic/photochromatic colorant	: 22 parts
Non-Thermochromatic pigment	: 1 part
Kerocene oil	: 70 parts
Acrylic soft binder (Americos Acrylic Binder 16000)	: 3 parts
Lissapol N	: 1 part
Water	: 3 parts

After printing, the samples were dried at 80^0C temperature for 3 min, followed by curing at 140^0C for 3 minutes in laboratory Steamer with Super Heater.

Dyeing

The fabric samples were dyed using photochromatic colorant, mixed photochromatic and thermochromic colorants and mixed photochromatic colorants with non-thermochromic pigments by continuous method (pad-dry-cure) using the following recipe:

Recipe: For100ml dye solution

Thermochromic/photochromatic colorant	: 24 ml
Non-Thermochromatic pigment	: 1 ml
Cationic agent (Americos AC NRL 9000)	: 10ml
Non-ionic dispersing levelling agent (Dispersol DX)	: 15 ml
Acrylic soft binder (Americos Acrylic Binder 16000)	: 20 ml
Water	: 30 ml

The fabric was padded at room temperature, dried at 80^0C for 3 min, followed by curing at 140^0C for 3 min.

Instrumental methods:

Color measurement

Color measurements of the dyed samples were carried out for according to the literature using a reflectance spectrophotometer (Christie and Bryant, 20005; Billah *et al.* 2008). It comprised of a hot-stage and a temperature controller, held against the aperture of a reflectance spectrophotometer. The spectrophotometer was calibrated using the black and white reference tiles provided by the manufacturer. The instrument was used with the small aperture, and specular reflectance and UV included. After temperature stabilization, the average of two measurements was obtained and L*, a* and b* values computed for illuminant D 65 and 10° observer.

For the measurement of color yield of photochromatic textile materials, it is necessary to control carefully several experimental factors, including temperature, because of its effect on the thermal reversion of the photochromic reaction, and the time interval between UV irradiating the sample and measurement. (Little and Christie, 2010). Developed methodologies to assess photochromic textile samples using independent UV irradiation in combination with a traditional color measurement system. They used traditional spectrophotometer along with a UV source with an emission maximum at 365 nm for sample irradiation. Samples were mounted at a distance of 4.5 cm below the horizontal UV source, which was contained in a cabinet and controlled temperature in the laboratory was maintained by localized air heating system. They optimized color measurement method, using the small aperture, specular included and UV excluded, a sample temperature of 24^0C and a time of 3 s between irradiation and measurement.

Wash fastness test

For determining the wash fastness of the both printed and dyed samples were subjected to the standard mild wash fastness test (test method ISO 105 CO3) (Bradford: SDC 1990). The traditional assessment method using grey-scale standards is not appropriate to provide wash fastness ratings for thermochromic and photochromatic textiles, in view of their dynamic color change properties. Hence, a comparative study on the color build-up on the test sample before and after the wash fastness test was used as a measure of the wash fastness behavior. Wash fastness was carried out at a wash wheel at $60^0 \pm 2^0$C for 30 minutes using 5 g/l standard soap and 2 g/l of anhydrous sodium carbonate at a liquor ratio of 50:1.

Light fastness test

Light fastness of the both printed and dyed samples was carried out according to AATCC test method 16-2004, color fastness to light (AATCC Test Method, 2004). To test the resistance of a material to fading in daylight, the sample is exposed to an accelerated fading instrument like Xentex Alpholm used in this investigation. The traditional assessment of light fastness using the blue wool light fastness standard is not appropriate to provide light fastness rating for thermochromic and photochromatic materials. Hence, a comparative study on the thermochromic and photochromatic color build up on the test sample before and after exposure to the Xenon lamp after a specific time interval was used as a measure of light fastness behavior. Light fastness was carried out at a Xenotest Alpholm (Atlas, Germany) using the following exposure conditions.

Table 2. Experimental condition for light fastness (AATCC test method 16-2004)

Component	Condition
Light Source	Xenon
Black Panel Temperature	63 ± 1^0C
Chamber Air Temperature	43 ± 1^0C
Relative Humidity, %	30±5
Irradiance W/m^2(300-400 nm)	48±1

RESULT AND DISCUSSION

Printed sample analysis:

Textile printing is the most versatile and important of the methods used for introducing color and design to textile fabrics. Considered analytically it is a process of bringing together a design idea, one or more colorants, and a textile substrate (usually a fabric), using a technique for applying the colorants with some precision. Production of different patterns using these chromic colorants is one of the most important parts of "smart" textile production. Different design can be produced by printing. Printing was carried out on the sample woven fabric using thermochromic, combination of thermochromic and non-thermochromic pigment and photochromatic colorants by screen printing method. Then the samples were dried at 80^0C for 3 minutes followed by curing at 140^0C for 3 minutes in the curing chamber. The printed sample which was printed with thermochromic red colorant appears as red color at temperature $T>T_c$ but when the temperature is higher than activation temperature T_c the sample become colorless. Similar type of state was observed when printing was carried out using a combination of thermochromic blue and conventional non-thermochromic yellow pigment in single step. The sample appears as green when $T>T_c$. This indicates that thermochromic blue and yellow pigment together produce green color. But the sample appears as yellow when temperature rises above the activation temperature T_c. This opens up the possibility of creating predetermined colors by combining conventional pigments with thermochromic pigments or combining thermochromic pigments of different activation temperatures.

Thermochromic colorant printed sample

Sample	Before heating	After heating	Activation temperature (T_c)
Thermochromic red printed Textiles (Americos Thermochromic Red)			28^0 C
Thermochromic blue and Non-thermochromic yellow pigments (Americos Thermochromic Light Blue & Texcron Yellow 5G/Sc)			27^0 C

In case of sample, which was printed with photochromatic blue colorants appear as colorless in absence of UV light or sunlight. But appear as blue in presence of UV light or sunlight.

Photochromatic colorant printed sample

Sample	Before UV light exposure	After UV light exposure	Irradiance W/m^2(300-400 nm)
Photochromatic blue printed sample (Americos Photochromic Blue)			48±1for 3 seconds

Wash Fastness:

Wash fastness of dyed textile is of great importance to the customer. It determines the durability of the applied color to repeated washing. Wash fastness properties of the sample which was printed using thermochromic colorants and non-thermochromic conventional pigment was carried out at a wash wheel according to ISO 105 CO3 method. The sample was washed repeatedly four times using above recipe. Color strength (K/S) and Color difference (ΔE) values on repeated washing for printed sample was determined by spectrophotometer and is given in table-3. Color measurement was carried out after each wash cycle and then compared with unwashed sample. It was found from the graph (Fig. 3) that the printed sample show good fastness to washing properties as color strength (K/S) of the sample decrease very low with no of repeated washing.

Table 3. Color strength (K/S) and Color difference Δ E values on repeated washing

Sample	**K/S**	**ΔE**
Unwashed	1.518	
1st wash	1.209	1.65
2nd wash	1.263	1.59
3rd wash	1.168	3.22
4th wash	1.097	4.4

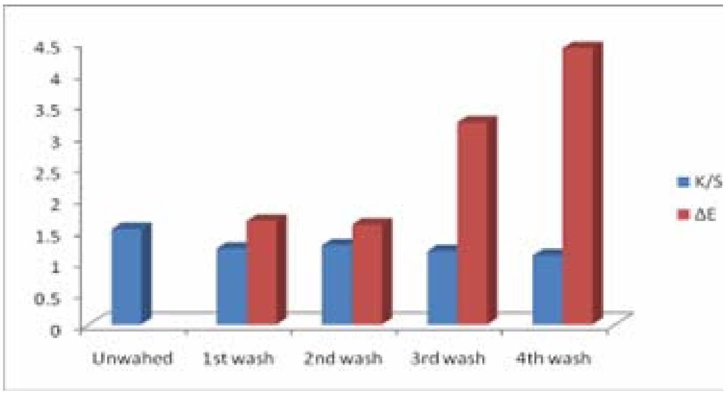

Fig. 3. Effect of Color strength (K/S) and Δ E on repeated washing

Light Fastness:

The ability of dyed textile to withstand prolonged sunlight exposure without fading or undergoing physical deterioration, usually referred to as light fastness in the case of traditional dyes, is largely determined by the photochemical characteristics of the absorbing dyestuff itself. In this investigation, the degree of photostability of four investigated thermochromic and photochromatic dyed sample was measured by spectrophotometer after each 30 minutes exposure to UVA irradiation up to 10 hours. It was found that the photostability of the sample printed with thermochromic blue and non-thermochromic conventional yellow pigments was found satisfactory. It was found from the figure that the color strength (K/S) of the sample decreases with the time of exposure under Xenon light.

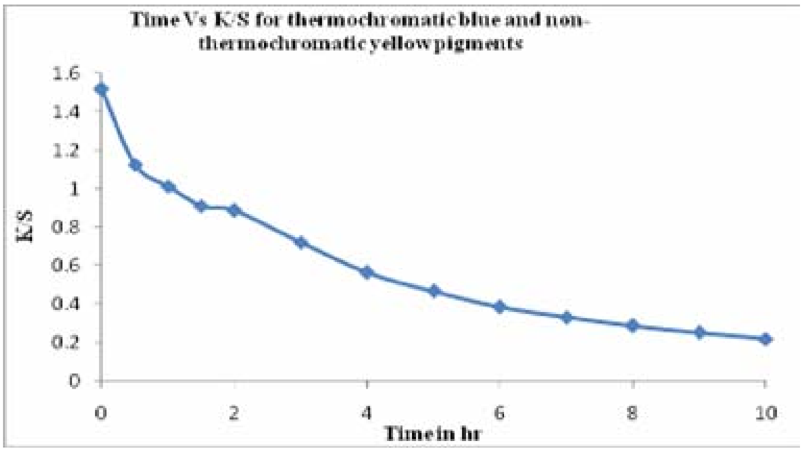

Fig. 4. Photostability curves for sample printed with thermochromic blue and non-thermochromic conventional yellow pigment

Dyeing using photochromic colorant

Photochromic red color was applied on to the fabric using pad-dry-cure method. Color measurement was carried out in presence and absence of UV light. It was found from the reflectance curves that the sample is colorless in absence of UV light. But when the dyed sample is exposed to UV light, it becomes colored and maximum reflectance, λ_{max} was found in red region (620-650nm) of the visible spectrum (Fig. 5). Reflectance data is given in the annexure-1.

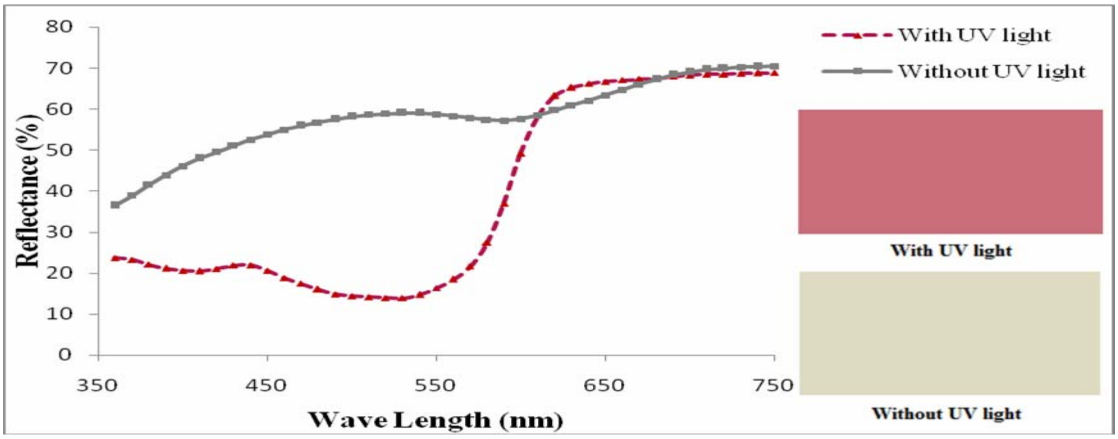

Fig. 5. Effect of UV light on reflectance of photochromic red colorant

Dyeing using mixed thermochromic and photochromic colorants

The sample which was prepared by dyeing the fabric with a combination of thermochromic blue and photochromic red colorants shows different colors in presence and absence of UV light and temperature (Fig. 6 & 7). The sample shows maximum reflectance λ_{max} in violet region (380-450nm) when the temperature of the sample was bellow the activation temperature (T~20^{o}C< T_c) of thermochromic colorant in presence of UV light. When at UV light was removed ($T < T_c$), sample turns to blue. At temperature higher than T_c, the sample turns to red (λ_{max} 620-750 nm) in presence of UV light. At higher temperature ($T > T_c$) and in absence of UV light, it turns colorless. Reflectance data is given in the annexure-II.

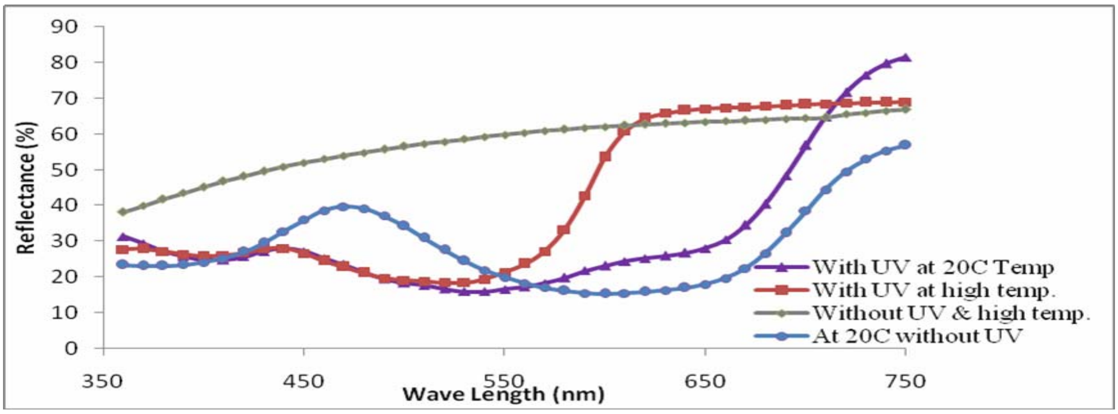

Fig. 6. Effect of UV light and temperature on reflectance for mixed thermochromic & photochromic colorant

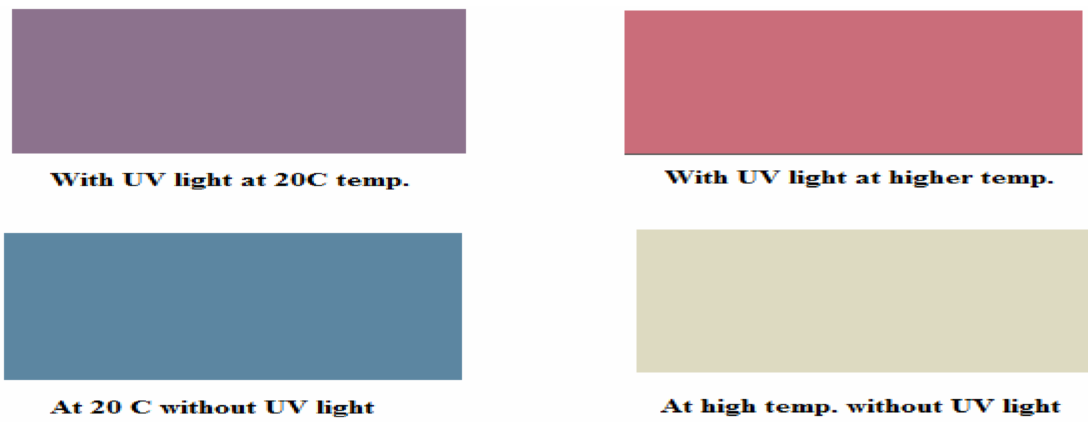

Fig. 7. Sample in presence and absence of UV light and temperature

Dyeing using mixed photochromic blue and yellow pigment

The dyed sample which was prepared using photochromic blue and non-thermochromic yellow pigment shows green color in presence of UV light but turns yellow when UV light was removed (Fig. 8) as blue color is faded out when it was exposed to UV light. Reflectance data is given in the annexure-III.

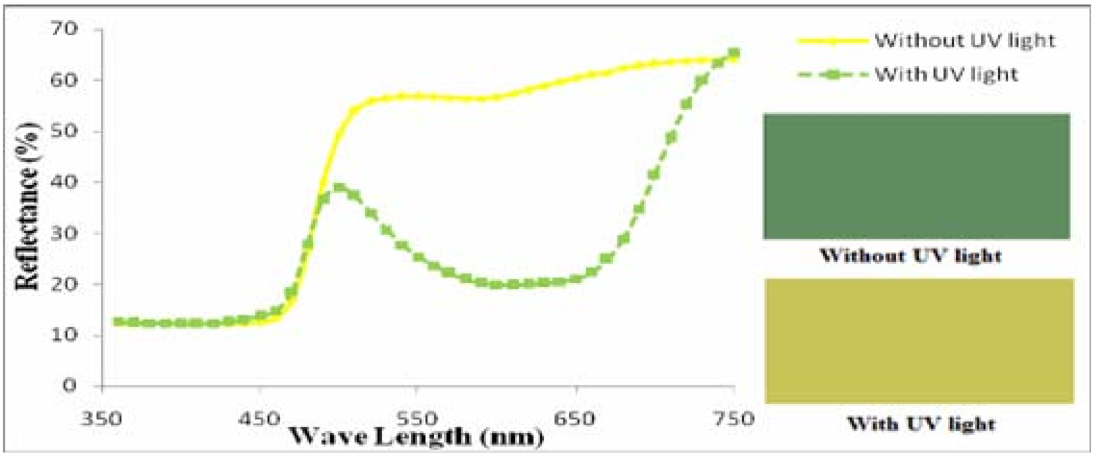

Fig. 8. Effect of UV light on reflectance for mixed photochromic colorant and conventional pigments

Wash fastness:

The wash fastness of the sample which was dyed with thermochromic blue and photochromatic red colorants show good fastness to wash (table-4). Though both color strength (K/S) of the sample decreases and Color difference ΔE increases with no of wash, it is within the satisfactory limit of wash fastness rating (Fig. 9).

Table 4. Color strength (K/S) and Color difference Δ E values on repeated washing

Sample	**K/S**	**ΔE**
Unwashed	1.076	
1st wash	0.921	0.91
2nd wash	0.853	1.85
3rd wash	0.83	2.03
4th wash	0.79	3.16

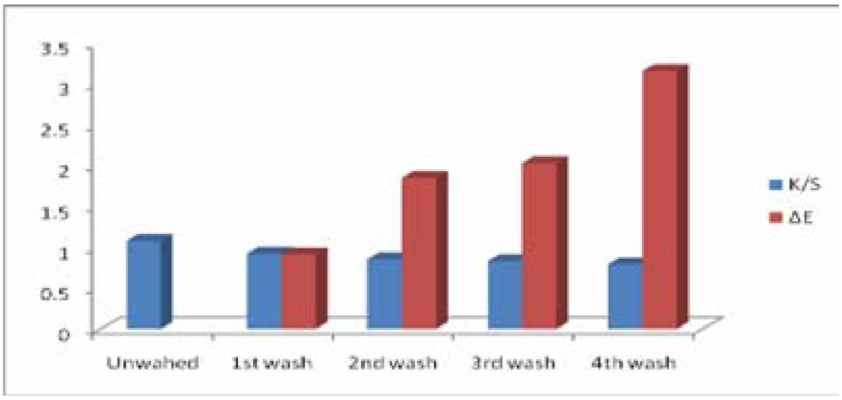

Fig. 9. Effect of Color strength (K/S) and Δ E on repeated washing

Light fastness

Light fastness of the sample which was dyed with thermochromic blue and photochromic red colorant was measured according to the above describe procedure. Light fastness of the dyed sample was found satisfactory though it color strength (K/S) was found decrease with time of exposure.

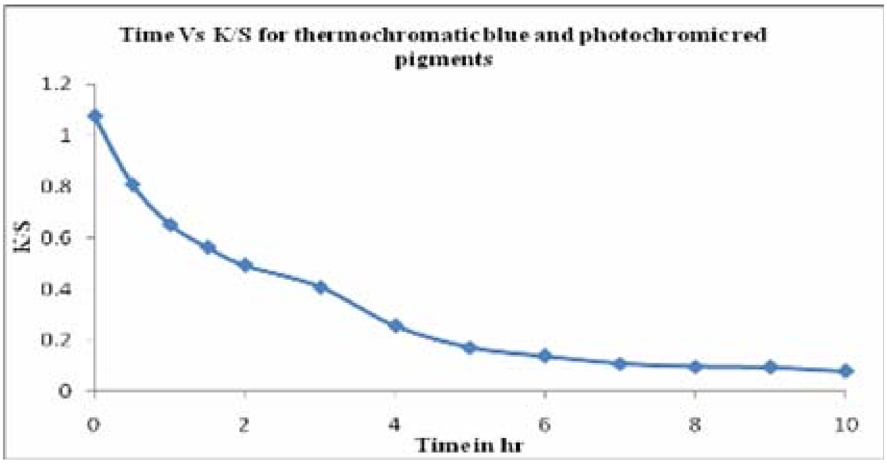

Fig.10. Photostability curves for sample dyed with thermochromic blue and photochromatic red colorants

CONCLUSION

Color is generally the most instantaneous visual aspect of textile design as color is emotive; it can move us and inspire us. So far the thermochromic, photochromic and non- thermochromic colorants were applied in textiles individually to a limited extend in specific fields. But the study concludes with a set of exciting new opportunities where the combined uses of them were possible for both dyeing and printing of textiles. In case of most important colorimetric properties like color fastness to washing and light, the samples exhibit good fastness to washing under repeater wash and moderate light stability under UV light. This approach widen the application of the color changing technology on textiles which may improve the textile designers' technical skills to produce unique and fashion challenging design like smart textiles as well as producing technical and functional clothing like camouflage textiles and so on.

REFERENCES

Aitken D, Burkinshaw SM, Griffiths J, Towns AD (1996) Textile applications of thermochromic systems. Review Progress in Coloration, pp 1-8.

Billah SMR, Christie RM, Shamey R (2008) Direct coloration of textiles with photochromic dyes. Part 1: Application of spiroindolinonaphthoxazines as disperse dyes to polyester, nylon and acrylic fabrics. Coloration Technology, pp 223-228.

Christie RM, Bryant ID (2005) An evaluation of thermochromic prints based on microencapsulated liquid crystals using variable temperature colour measurement. Coloration Technology, pp 187-192.

Christie RM, Robertson S, Taylor S (2007) Design Concepts for a Temperature-sensitive Environment Using Thermochromic Color Change. Color: Design & Creativity, pp 1-11.

Corns SN, Partington SM, Towns AD (2009) Industrial organic photochromatic dyes. Coloration Technology, pp 249-261.

Dawson TL (2010) Changing colors: now you see them, now you don't. Coloration Technology, pp 77-188.

Kulcar R, Friskovec M, Hauptman N, Vesel A, Gunde MK (2010) Colorimetric properties of reversible thermochromic ink. Dyes and Pigments, pp 271-277.

Kulcar R, Friskovec M, Gundec MK, Knesaureka N (2011) Dynamic colorimetric properties of mixed thermochromic printing inks. Coloration Technology, pp 411-417.

Little AF, Christie RM (2010) Textile applications of photochromic dyes. Part 1: establishment of a methodology for evaluation of photochromic textiles using traditional colour measurement. Coloration Technology, pp 157- 163.