COLOUR SPREAD: LIGHT, THERMOCHROMICS AND CONVENTIONAL PIGMENTS

Isabel CABRAL & A. P. SOUTO

Abstract: *With the colour change materials that react to heat stimulus – thermochromics – the possibilities of mixture solutions with conventional pigments emphasizes a re-thinking of colour as dynamic design material. In this work, smart materials are applied in order to achieve textiles that can change from one initial colour to others, namely, those that have been combined to create them. The aim is to transform the light that goes through them, designing dynamic ambience light, without acting upon the light source.*

Thermochromics and conventional pigments have been combined through different colours and measured in intensity and colour of the light parameters.

The smart materials applied to textile fabrics changes the light transmitted, once the pigments require light to be absorbed to obtain colour. The results reveal that thermochromics and conventional pigments can be combined and applied in textile filters, providing the ability to transform the monochromatic light to colour, in order to create dynamic ambience light.

Key words: *Smart Textiles, Thermochromism, Colour, Textile Design, Dynamic Ambience Light*

1. Introduction

The introduction of active behaviour on textiles, that traditionally perform a passive functionality, have been reached through the progress of new materials, technologies and the assembly of multidisciplinary design/work teams. When smart materials are applied to textile substrates, in order to “sense and react to environmental conditions or stimuli, such as those from mechanical, thermal, chemical, electrical, magnetic or other sources” [1] smart textiles are designed. Along aesthetics and functional variables, the design practice of smart textile structures are developed particularly in research and experimental projects where designers work by the material itself, “with the purpose of exploring and expanding the boundaries of the design space, in order to deepen our understanding of what can be done”. [2]

Despite the concept of dynamics of smart textiles is boosted by technology innovation, new challenges don’t rely merely on technical possibilities. By designing solutions that interact in a system, as in other design domains, we move in a platform where products exist as a medium between people and within the materials´ environment, [3] designed to “enhance the quality of life in some way and have added value in terms of functionality and performance, (…) stimulate the intellect such as experience and sensory and emotional fulfilment”. [4]

Colour is one of the main visual aspects of textiles, and thus, an essential variable in design practice. The human chromatic perception depends on the nature of the human eye, the brain´s interpretation, the light source and the optical properties of the substances. [5] As the materials can reflect their own colour and absorb all the other colours of the light spectrum with thermochromic (TC) materials a heat stimuli changes the substance´s molecular structure, affecting their spectral reflectivity and the phenomena is observed with the change of colour. [6]

The TC materials are suited to textile applications in form of pigments or dyestuff. Available in diverse predefined variation temperature, they can perform reversible colour change ability, fading away above the trigger temperature and returning to the pre-established colour, bellow it. Able to be mixed with the conventional pigments, instead of a clear or colourless effect, the heat variation achieves diverse possibilities in the colour change performance: bellow the temperature variation it’s possible to see the result of the colours addition of the pigments, TC and conventional; above trigger temperature it's only possible to observe the colour of the conventional pigment, because the TC pigment fades. This enables designers to explore a range of colours and material combinations.

When light goes through an object, the proportion of light absorbed also interferes in the light intensity reflected - transmittance. [7] Dark colours absorb a vast intensity of the visible light spectrum than lighter colours and, as a consequence, incident light that passes through a thermochromic sample also changes the light intensity when they are above or bellow their trigger temperature.

The possibilities of mixture solutions of TC and conventional pigments, emphasize issues as to what the colour change performance can inform, transform or conduct, and how colour can be worked as dynamic design material. In this paper, the approach in researching TC textiles, is developed through different TC and conventional pigment combinations in order to change from similar (or equal) colours to different ones, when they are above the temperature variation. The conception of innovative light filters with smart materials will transform the light that goes through TC textile structures, designing dynamic ambience light without acting upon the light source. By selecting TC and conventional pigments with two colours (magenta and blue), a set of different concentration samples for each colour has been developed. The samples were measured in a spectrophotometer and a database was made. A standard sample was printed as pattern colour with TC magenta and TC blue. Then it was measured by spectrophotometer and two recipes were formulated: solutions of TC magenta with conventional pigment blue and TC blue with conventional pigment magenta, to achieve optical similarity between samples..

New samples were printed, measured and compared in spectral reflectance and light intensity parameters. Afterwards, for a better visual perception of the filtering the light effect, through the trigger temperature change, a photograph record was done.

2. Materials and Methods

In this study was used textile plain weave : 50% cotton and polyester, 115 g/m^2, 15,0 and 15,5 warp and weft (tex), with a density of 41 ends/cm and 31 picks/cm.

The pigments handled were the Varioterm AC Base 27 (27°C TC heat sensitive pigment), blu nuovo solido and magenta; conventional pigments ATUSMIC Magnaprint eco pink H5B and blue HB, and the binder was the ATUSMIC Magnaprint ND extra.

All the procedures were developed in a context of ambient temperature, bellow the temperature variation of the TC pigments used (27ºC).

2.1. Samples with different concentrations of TC and conventional pigments

A set of screen printed samples were developed, with a concentration range for each pigment:
A - TC pigment 27ºC magenta 6-11% (6 samples),
B - TC pigment 27ºC blue 6-11% (6 samples),
C - conventional pigment pink 1-5% (5 samples) and
D - conventional pigment blue 1-5% (5 samples).

The printing pastes were applied on a Zimmer Mini MDF R541 screen printing table. On each sample, an open screen was placed above the fabric and each solution was applied in one layer. After drying, each sample was thermo fixed in an oven at 150ºC during 3 min.

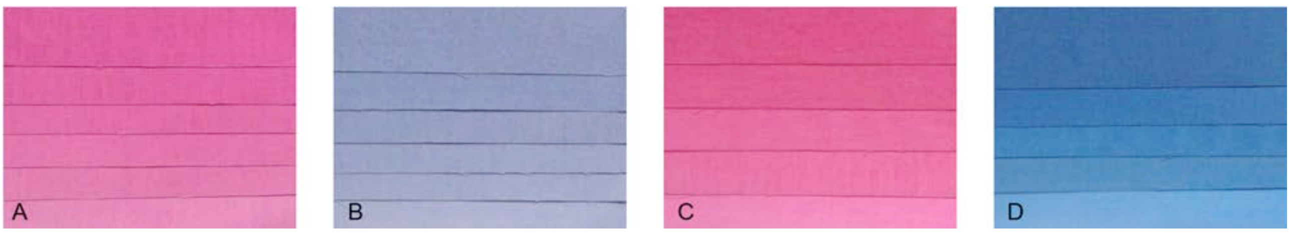

Figure 1: Samples with different concentrations of TC (A and B) and conventional pigments (C and D), increasing concentration from the bottom upwards.

A spectrophotometer was used to measure each screen printed sample, in order to build a pigment concentration database, for the following procedures.

2.2. Samples with a mixture of TC and conventional pigments

A mixture solution of TC pigments 27ºC magenta and blue, both with 11% concentration, was screen printed to be used as the main colour sample X.

The sample was measured in the spectrophotometer and, with the previous database, two recipes were formulated, as follows:

For 100g of the printing paste:
Y: 0,616g conventional pigment magenta and 6,128g TC pigment blue solution;
Z: 0,131g conventional pigment blue and 5,047g TC pigment magenta solution.

2.3. Optical measurements

In order to attain a comparative analysis of the optical performance of X, Y and Z samples, a set of data was acquired through the measurements, above and bellow the trigger temperature of the TC applied.

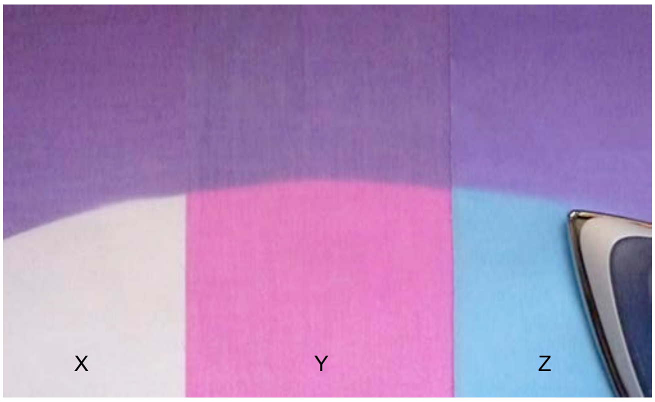

Figure 2: X, Y and Z samples (respectively), with the lower half heated above 27ºC

2.3.1. Spectral reflectance measurement

The samples were measured in the spectrophotometer datacolor International, SF600 Plus – CT, and the data was set in colour coordinates and spectral curves. This instrument measures the amount of light reflected at each wavelength of visible light spectrum (approximately 380 to 760 nm), according to the average colour on a defined aperture. [8]

The spectral curves provide a visual profile of the colour wavelength characteristics, showing the radiant power reflected at each wavelength in the visible light spectrum. X, Y and Z samples spectral curve were overlapping in figure 3 - respecting the measurement bellow 27ºC – in order to compare similarities and differences between colours achieved.

2.3.2 Light intensity measurement

To measure the light intensity that goes through the textile samples, a light box was built with a 34,0x30,0x25,0cm cardboard box. In the centre of a 34,0x25,0cm side, a 28,0x18,0 cm rectangle was cut, and a k-line frame with 42,5x 29,5cm exterior and 18,0x14,0cm interior was glued (another k-line frame, with the same dimensions, was cut in order to cover the textile sample after it was placed). A 15W fluorescent lamp was setup on the opposite side of the rectangular hole. The exterior surface and the inner corners were covered with black cardboard to ensure that the only output of light would be through the sample.

In a dark room, the lux meter (DELTA OHM – HD 2302.0 Light Meter) was placed 1m from the light box's open side, pointing towards the sample centre.

For each sample the following procedure was done:
The sample was placed in the light box's open side, taped, and the k-line frame was set above and covered. With the light box sample side placed vertically, the lamp was turned on and the luxmeter value was registered. In order to get the light intensity in different points of the same sample, the light box was moved 2cm to the left, the luxmeter value registered and the measurement repeated with a 2cm increment to the left. After this measurement, the light box was set in the initial position and with a dryer warming up the sample above 27ºC, the registered luxmeter value was repeated with the other sequence of measurements.

2.3.3 Photographic registry

A Canon EOS 20D camera with 18-55mm lens was used for the photographic register. Each sample placed on the light box was registered bellow and above 27ºC, with the following photographic setup: Exposure time: 1/25, ISO: 800 and Aperture: 8.0.

3. Results and Discussion

The colour measurement results, presented on table 1, show the values obtained in each sample, where L* for lightness and as colour opponent dimension a* – green/red and b* – blue/yellow.

Table 1: Measurement with the illuminant D65/10

	L*	a*	b*	C*	h
X	55,34	19,03	-27,74	33,64	304,45
Y	54,92	15,54	-28,77	32,69	298,38
Z	56,76	18,23	-30,28	35,34	301,06

Regarding that X was set as the pattern colour, it's possible to undertake the following comparative analysis:
L*: X is darker than Z and lighter than Y
a*: X is more red than Z, and Y
b*: X is less blue than Y, and Z

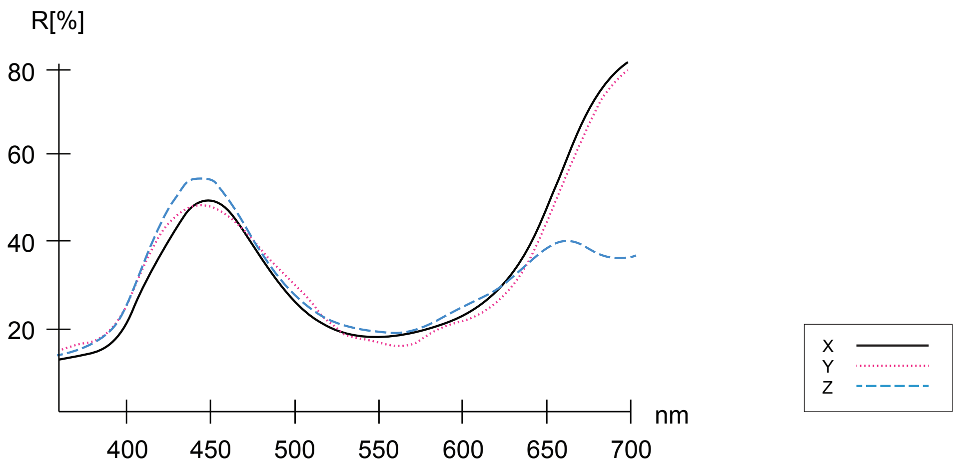

Figure 3: X, Y and Z samples spectral curve, bellow 27ºC

With the overlapping of the spectral curves on the figure 3, the relation between the spectral reflectance versus wavelength of each sample is represented. At a temperature bellow 27ºC, Z has the blue higher reflectance (on approximately 450-490 nm) and the lower reflectance on red wavelength (about 620-740 nm), while X and Y have obtained similar curves.

The photographic record, figure 4, of the X, Y and Z samples transmittance, provides a visual confirmation of similarities when the three samples are bellow the TC pigments temperature variation. When they are above the trigger temperature, the TC pigment fades away and the transmittance is detected through the lack of colour on sample X, the conventional pigment magenta on sample Y and blue on sample Z.

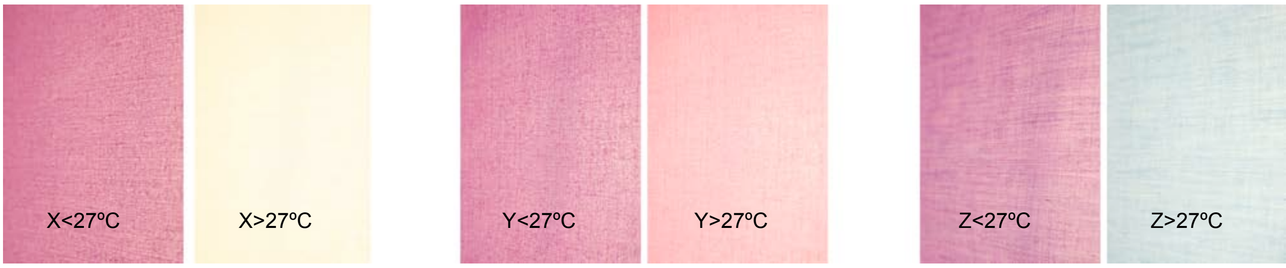

Figure 4: Photos of transmittance light for X, Y and Z samples

Table 2: Mean values of light intensities with temperature below and above 27ºC

	Lux (lx)		difference (%) temp<27ºc to temp>27ºc
	temp<27ºc	temp>27ºc	
X	1,23	6,86	82%
Y	2,01	4,24	53%
Z	1,96	3,54	45%

According with the results shown on the table 2, is possible to conclude:

The colour of the samples changes the light intensity that passes through them. The intensity is higher when the temperature is above 27ºC.

The colours of X, Y and Z samples are similar when they are bellow 27ºC, even if the transmittance have some differences. The greater light intensity difference is observed, when the temperature is above 27ºC, acknowledging that dark colours absorb more light than lighter colours.

The percentual difference of light intensity that goes through the samples, above and bellow their temperature variation, increase from the colour perceived above 27ºC, sample X without conventional pigments (colourless), sample Y with magenta conventional pigment (magenta) and sample Z with blue conventional pigment (blue).

4. Conclusions

Innovation in the emerging field of smart textiles is providing designers with new challenging materials and technologies. This requires new knowledge and practice in order to explore their potential to be integrated in our products and surrounding areas.

Studying the TC colour change technology in textiles, the textile filters effect was developed through intrinsic behaviour characteristics of the TC pigments and the combination with conventional pigments. Colour and light, as a visual perception, plays a significant role in our daily lives and provides insight in the development of diverse design domains.

The three samples developed present similar colours when they are bellow the variation temperature, however the measured transmittance is different between them and the combination of two TC pigments (X sample) present the lower value. Of all textile samples, X achieved a maximum lux change of 82%.

In this work has been developed a process of how to combine and print with TC and conventional pigments, in order to reach similar colours bellow the TC trigger temperature and different ones above it.

The difference of light transmittance depends on textile substrate and dyeing characteristics, thus, the presented phenomena offer an emerging design potential, when used for the creation of light projection scenarios. This undertakes an interwoven variable on experience, expression and functionality and also raises the specific question of what can stimulate heat change if the environment temperature is not the activation alternative.

Achieving an understanding of the process development working with light, TC and conventional pigments, this research develops a basis for procedures in textile design applications, that provide the ability to extend monochromatic light in a colour spread ambience.

Future Work

The systematization to achieve a specific colour, through TC and conventional pigment combination, delineate the possibility to adjust configurations, transforming the textile filters in multiple colours by heat stimulus.

Future studies should consider the methodology followed in this work, as well as assembly of a new screen printing cycle to a sample that has been dyed before.

Developing several design patterns with TC pigments in textiles, when temperature stimulus is applied, the colour spread effect occurs and dynamic ambience light is designed, without acting upon the light source.

References

[1] Tao, X.: *Smart Fibres, Fabrics and Clothing: Fundamentals and Applications,* Woodhead Publishing Limited, 0-8493-1172-1, Cambridge, (2001), pp. 2-3
[2] Eriksson, D. et al.: *IT+Textiles*, The Interactive Institute and University of Borås The Swedish School of Textiles, 978-91-975576-5-8, Borås, (2010), pp. 36-37
[3] Kolko, J.: *Thoughts on Interaction Design*, Brown Bear, 978-0-9788538-0-8, Georgia, (2007)
[4] Baurley, S.: Interactive and Experiential Design in Smart Textiles Products and Applications, *Personal and Ubiquitous Computing*, Vol.8 (2004) No.3-4, pp. 274, 1617-4909
[5] Xin, J. H.: *Total Colour Management in Textiles*, Woodhead Publishing and The Textile Institute, 978-1-85573-923-9, Cambridge, (2006)
[6] Addington, M. & Schodek, D.: *Smart Materials and New Technologies for the Architecture and Design Professions*, Architectural Press, 0-7506-6225-5, Oxford, (2005), pp-15
[7] Bamfield, P. & Hutchings, M. G.: *Chromic Phenomena: Technological Applications of Colour Chemistry*, The Royal Society of Chemistry, 978-1-84755-868-8, Cambridge, (2010)
[8] Xin, J. H.: *Total Colour Management in Textiles*, Woodhead Publishing and The Textile Institute, 978-1-85573-923-9, Cambridge, (2006), pp.97

Author(s):

Isabel CABRAL, Ph.D. Student
University of Minho, Guimarães, School of Engineering, Department of Textile Engineering
Campus de Azurém, 4800-058 Guimarães, Portugal
Phone: +(351) 967787308 Fax: +(351) 253510293 E-mail: diascabral@gmail.com

Prof. António Pedro SOUTO, PhD.
University of Minho, Guimarães, School of Engineering, Department of Textile Engineering
Campus de Azurém, 4800-058 Guimarães, Portugal
Phone: +(351) 253510280 Fax: +(351) 253510293 E-mail: souto@det.uminho.pt