Chameleon Inspired Outerwear Designs Achieved via Photochromic and Thermochromic Pigments

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Abstract:

Lately it has been recognized that the growth of materials and textiles are on continuous advancement due to the interest of researchers. Colour change technology has been reflected in many products and materials lately due to the increase of demand of colour changing within the market. Some of these demands may vary from being beneficial and some may be with the aim of expressing creativeness. Colour-Changing technology is being achieved through various approaches, one of which is the chromic materials. Such materials are both photochromic and thermochromic colorants. They are well established colorants in the market. Photochromic Colorant has the ability to change colour when exposed to sunlight while Thermochomic Colorant changes colour when exposed to heat. These types of colorants have become a major focus in research due to their potential. They have been used in various applications such as medical thermography, plastic strip thermometers, food packaging, etc. In the last few years however, the application of such colorants on textiles have picked up significantly which will allow the potential to enrich the market with such products. This paper focuses on pigments of both photochromic and thermochromic which were applied on fabrics and then followed by the application of them in designs. The designs were inspired from the chameleon since another term for chromic materials is the "chameleon" materials. Durability and comfort experiments were executed on the chromic fabrics prior to applying it on the executed designs with the aim to distinguish the areas in which should be applied.

Keywords:

Photochromic, Thermochromic, chromic, chameleon, clothing design.

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Aims and Objectives of the Research:

First, is to be able to implement one of the colour-change technologies on garments. Second, to enable to provide for the customers the possibility of having products that provides different looks. Last but not least, is to study and gain the knowledge of the effect of these pigments on fabrics and how it affects durability and comfortness of the fabric.

Problem of the Research:

It has been recognized that there is a lack of usage of such technology within the fashion industry.

Significance of the Research:

- To show the differences between different technological aspects of the same concept of color changing.
- The ability to succeed in producing fabrics that has the ability to change in its appearance.
- Designing and implement outfits inspired from the chameleon and implement the colour concept on them.

Hypotheses of the Research:

Is to be able to implement clothing inspired from the chameleon and achieve the colour-change aspect on it.

Research Methodology:

- An analytical approach to study the differences between the photochromic and the thermochromic.
- An experimental approach to study the durability and comfort of fabric when chromic pigments are applied on it.
- To design lines inspired from the chameleon.
- To implement selected outfits and apply on them both the thermochromic and photochromic pigments.

Introduction:

Fashionable clothes have always relied on the textiles used in the process since the beginning of man-kind. Some of these clothes and textiles maybe used to fulfill a certain need (1). It has been realized lately when combining Fashion, Science and Technology, all three have been the focus of interest for the past decade especially with the emerging of research on smart textiles. Chromism means the reversible change of colour which is also reflected on its physical properties. With the use of chromic colorants, these colorants were used in the manufacturing of various products since they have the capability to be responsive and adaptive. Colour changing textiles respond and adapt to external environmental conditions and stimuli (2-4).

Chromic materials have been approached through different applications. Lately, artists and creative designers have had interest in such smart materials due to the fact it offers a unique and challenging design opportunities since they interact, respond and dynamically change to be a source of creativeness and expressionism (3).

Over the past 50 years, thousands of photochromic and thermochromic molecules have been synthesized. Only few of them have been commercialized. This is due to the complexity of their technicality and the developing process (4). Photochromic materials mainly change colour due to irradiation with ultraviolet (UV) or light and revert back to its original state when the source

of illumination is removed. The changes of colour that occurs is usually the transition from colour to colourless or by mixing it with the proper dyes, the colour would change to a different colour when exposed to sunlight (5). Photochromic compounds that are used in textiles are mainly for decorative effects such as prints and embroideries in garments. Such garments may be like T-shirts, handbags, caps, night wear, etc (3). The alterations from colour to colourless or to a different colour may last up to 2000 times in and out of the UV light which is considered to be equivalent to the lifetime of a garment (6). Thermochromic materials, however, changes colour with the changes of temperature. Changes in colour may be due to direct contact with the surface or due to the environmental surroundings; whether it's heat or cold. Thermochromic materials that contain encapsulated dyes were first developed in the 1970s which was patented by a Japanese company and consequently were used then in textile materials (3). There are two types of thermochromic systems that both have been applied on textiles and they are as follows, liquid crystal and molecular arrangement. Materials that use liquid crystals show different colours at different temperatures and this is due to its selective reflection of wavelengths extracted from the light. This material, liquid crystal, is used in the manufacture of thermochromic printing ink since it has the capability to express very fine coloured images. But yet on the other hand the colour density of it is considered to be low and the cost of production is quite high. As for the molecular arrangement, it is affected by temperature or by the alteration in its polarity of the solvent and/or the pH which due to its sensitivity it reflects the thermochromic behavior (7).

Thermochromic and photochromic pigments have been reflected by some textile designers in their designs whom have combined between aesthetic and functionality (8). It has been reported that Elizabeth de Senneville was the first to produce clothes that change colours in 1999. The clothes' stimuli that she presented to her customers were thermochromic (9). Linda Worbin has used within her research carbon fibers that were woven into the fabrics with the aim to produce a color and a pattern change on the fabric when a power supply is sustained (10). Maggie Orth produced an electric plaid that has the potential to change colour (11). "The Skin Stories: Charting and Mapping the skin" is a multidisciplinary research executed by Berzina (12) where she presented through her work thermochromism through different approaches. In this paper it has been focused to produce two different garments representing the thermochromic and photochromic respectively while executing both comfort and durability experiments onto the fabric.

Experimental

The experimental has been divided into two parts. The first is the preparation of the chromic pigments and the tests that have been carried on the samples. The second part is the designing process. It is true that chromic colorants can be applied on clothing through various different methods but in this paper it has been mainly focused that it will be applied through hand painting for both thermochromic and photochromic colorants.

Preparation of Pigments

There were certain parameters kept into consideration to be constant throughout the experiment. These parameters were the dye, the formulation of the paste and the fabric use. Although it has been clarified by Anna et al (13) that the preparation of chromic pigment is executed through firstly dissolving the chromic powder in acetone and then adding the solution drop wise to the

thickener yet in this experiment the powder was directly added to the thickener. The print paste was prepared by adding to the thickener paste the chromic powder with a ratio of 2:1 respectively. The paste was then applied on to the fabric using a brush since it is the mean that will be used when applying the chromic pigments to clothing. The fabric that was used wool/polyester. The printed textiles showed significant reversible colour change when exposed to UV, sunlight and for thermochromic textile, when it is in contact with the human body indicating that both pigments have been successfully prepared.

Both samples, thermochromic and photochromic fabrics, were then tested. The tests that were executed focused on comfort and colour fastness and they are as follows:

1) **Wettability:** it is the test for fabrics containing hydrophilic fibers. The test is defined as the time it takes in seconds for a drop of water to be absorbed into the fabric. A fabric that absorbs the drop of water in more than 200s is considered to be unwettable. The specimen is clamped to a frame. A burette with a standard tip size is clamped 6mm above the horizontal surface on the sample as shown in Figure 1. At an angle of 45^{o}, a source of illumination is set and the sample/ fabric is viewed at a 45^{o} angle from the opposite direction of the illumination. The counting of time starts when the drop of the water touched the surface of the fabric. When the diffuse reflection from the drop of water vanishes and it is no longer visible, the timing is stopped. Five areas of each specimen were tested. (14)

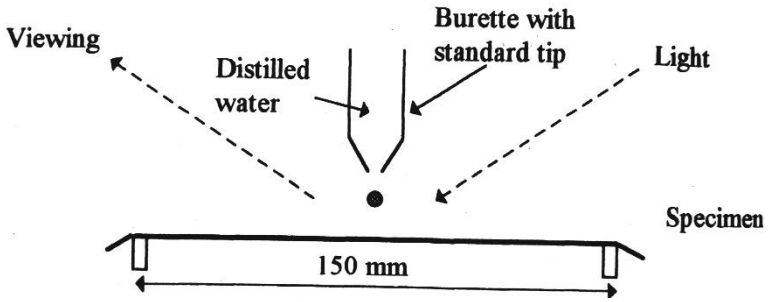


Figure 1. Wettability Experiment

2) **Thermal transmittance:** (ASTM D1518 Standard Test Method for Thermal Transmittance of Textile Materials)

This test method covers the measurement of the thermal resistance, under steady-state conditions, of battings and batting/fabric systems. It measures the heat transfer from a warm, dry, constant-temperature, horizontal flat-plate up through a layer of the test material to a cool atmosphere and calculates the resistance of the material. The measurements are made under still air conditions or with a horizontal air flow over the specimen. (15)

3) **Air Permeability:** (ASTM D737 standard test method for air permeability)

It is a test that is very significant since it measures the performance of a fabric. It can be used to provide an indication of the breathability of weather-resistant, rainproof fabrics, and/or coated fabrics. The test also detects the changes occurred during the manufacturing process (16)

4) Colour Fastness to Crocking: (AATCC 8-2016)

This test method is for determining the amount of color that transfers from the surface of colored textile materials to other surfaces by rubbing. This type of experiment is applicable to textiles that are dyed, printed or otherwise colored.

The procedure of the test employs white test cloth squares, both dry and wet with water, are

given. Washing, drycleaning, shrinkage, ironing, finishing, etc., may affect the degree of color transfer from a material, the test may be made before, after, or before and after such treatments. (17)

5) **Colour Fastness to Laundering:** (AATCC 61-2013 A1)

This test is to evaluate the colorfastness of textiles after washing. These fabrics are expected to have resistance to frequent laundering. The fabric color loss and surface changes resulting from detergent solution and abrasive action of five typical hand or home launderings, with or without chlorine, are roughly approximated by one 45 min test. However, the staining effect produced by five typical hand or home launderings cannot always be predicted by the 45 min test. Staining is a function of the ratio of colored to undyed fabrics, fiber content of fabrics in the wash load and other end-use conditions which are not always predictable. (18)

Designing Process

As for the designing process, since chromic materials are also known as chameleon materials (3), chameleons were used as the source of inspiration for designing lines of clothing. The chameleon was first analyzed whether its lines or the colours it reverses into as shown in figures 2.

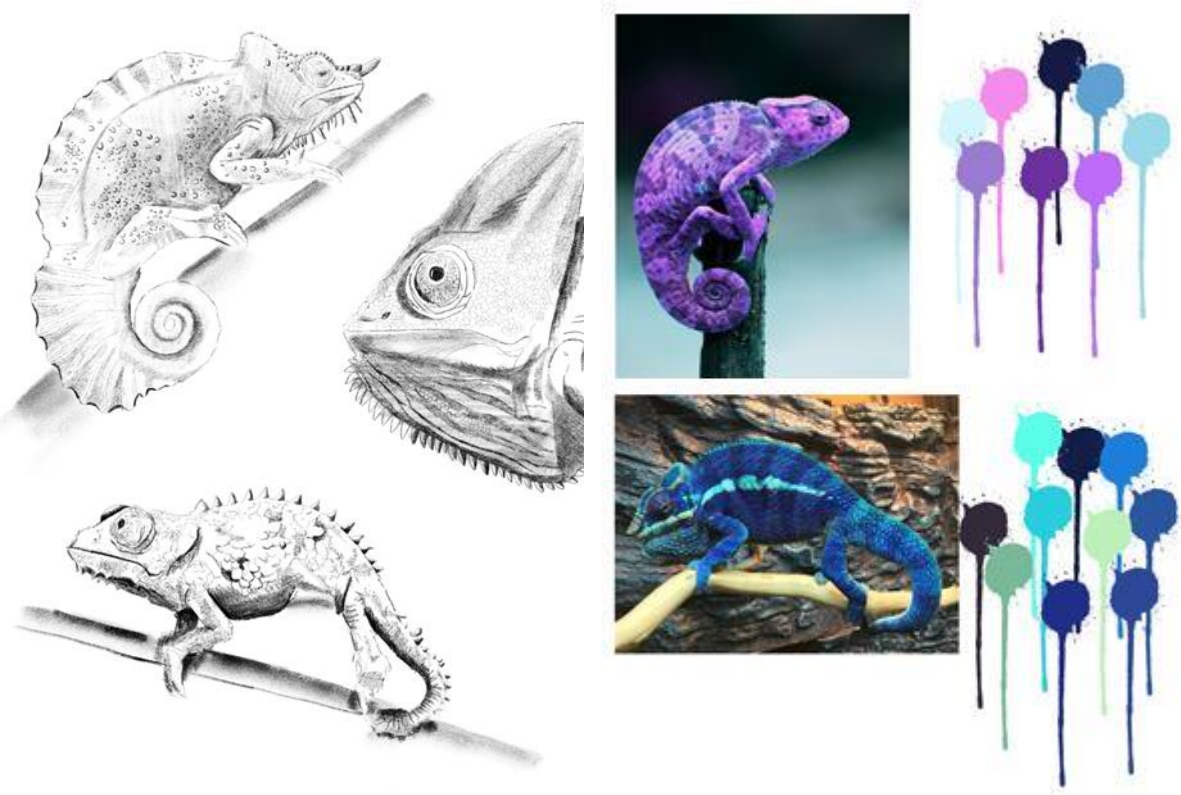


Figure.2 Analysis Process of the Chameleon

The chromic pigments were then applied on fabrics using a painting brush and/or a sponge. One piece from each line, an ensemble and a dress, were implemented.

Results and Discussions

In the wettability experiment, it was executed on the back surface of the fabric that will be in direct contact with the wearer. Both thermochromic and photochromic samples were compared

to the unprinted fabric which will be addressed as the Blank Sample throughout the paper. Figure.3 represents the average reading of five trials executed on the samples in different areas. It shows in figure.3 that it only took 1.3 seconds for the photochromic sample to absorb the distillated water while it took the thermochromic sample 2.1 seconds. There is more than 60 seconds difference between them and the blank sample which was 66 seconds. This is an indication that the paste formulation did not cause for the pores within the fabric to be blocked. In the thermal transmittance experiment, it was found that the thermochromic has the least value of 1.18, while the blank fabric is 1.36 and the highest is the photochromic with a value of 1.51. Figure.4

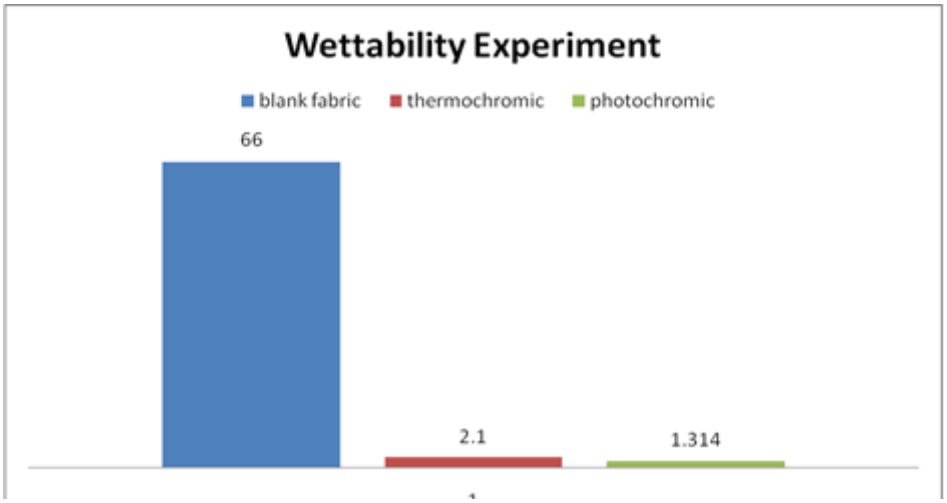


Figure.3 Comparison of Wettability Experiment

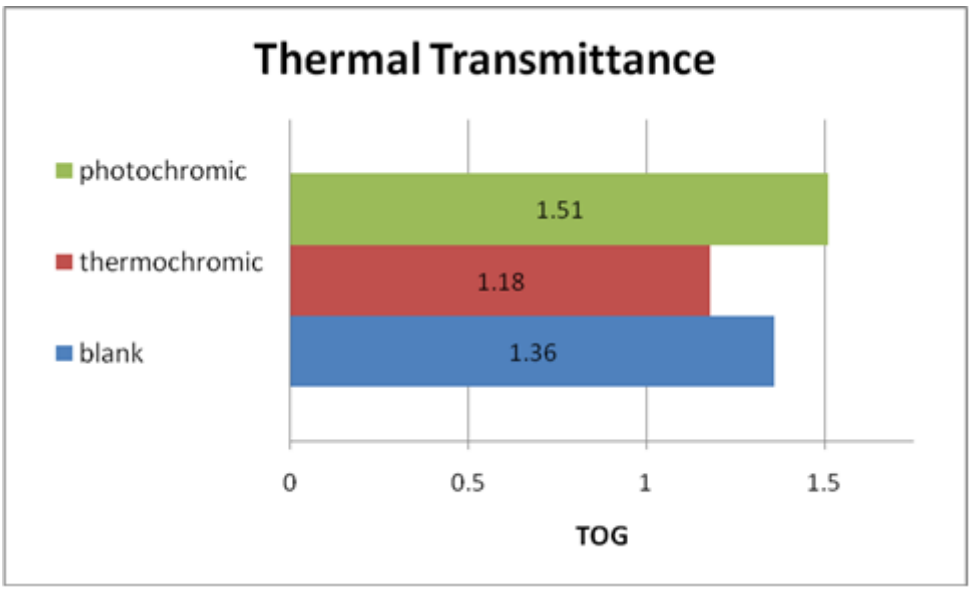


Figure.4 Comparison of Thermal Transmittance

In regards to the Air permeability test, 5 different trials were executed on each of the samples. Table 1 reflects the values of each trial. It has been observed that the differences between the blank sample and the chromic samples are quite tremendous which from it, it is expressed that the chromic samples have very low capacity to allow air passing through the fabric. Figure.5 represents the average value of five trials of each sample.

Sample	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
Blank	148	149	146	146.2	149.5
Thermochomic	0.668	0.706	0.687	0.689	0.669
Photochromic	0.675	0.68	0.679	0.68	0.684

Table.1 Five trials readings of Air Permeability of blank, thermochromic and photochromic samples (ml.cm^2.sec)

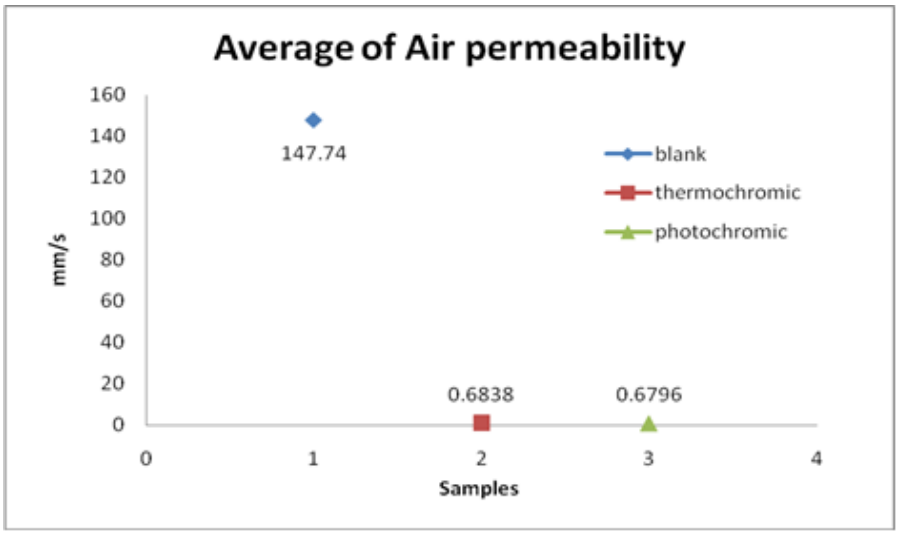


Figure.5 Comparison of Average values of Air Permeability of samples

Last but not least, are the colour fastness to crocking and laundering. These types of experiment are considered to be of a great importance to the consumer. Two types of colour fastness tests were applied on the samples which were colour fastness to crocking and colour fastness to laundering. Samples were compared to a grayscale in order to determine the amount of colour lost in the case of laundering or transfered in the case of crocking. Table.2

	Crocking		Laundering						
Sample	**Dry**	**Wet**	**Change of Colour**	**Wool**	**Acrylic**	**Polyester**	**nylon**	**cotton**	**acetate**
Thermochromic	4 or 5	3	4	3 or 4	4	3 or 4	3 or 4	3 or 4	4 or 5
Photochromic	3 or 4	3	4 or 5	4	4 or 5	4 or 5	4 or 5	4 or 5	4 or 5

Table.2 Readings of colour fastness to crocking and to laundering of Thermochromic and photochromic samples using a grayscale.

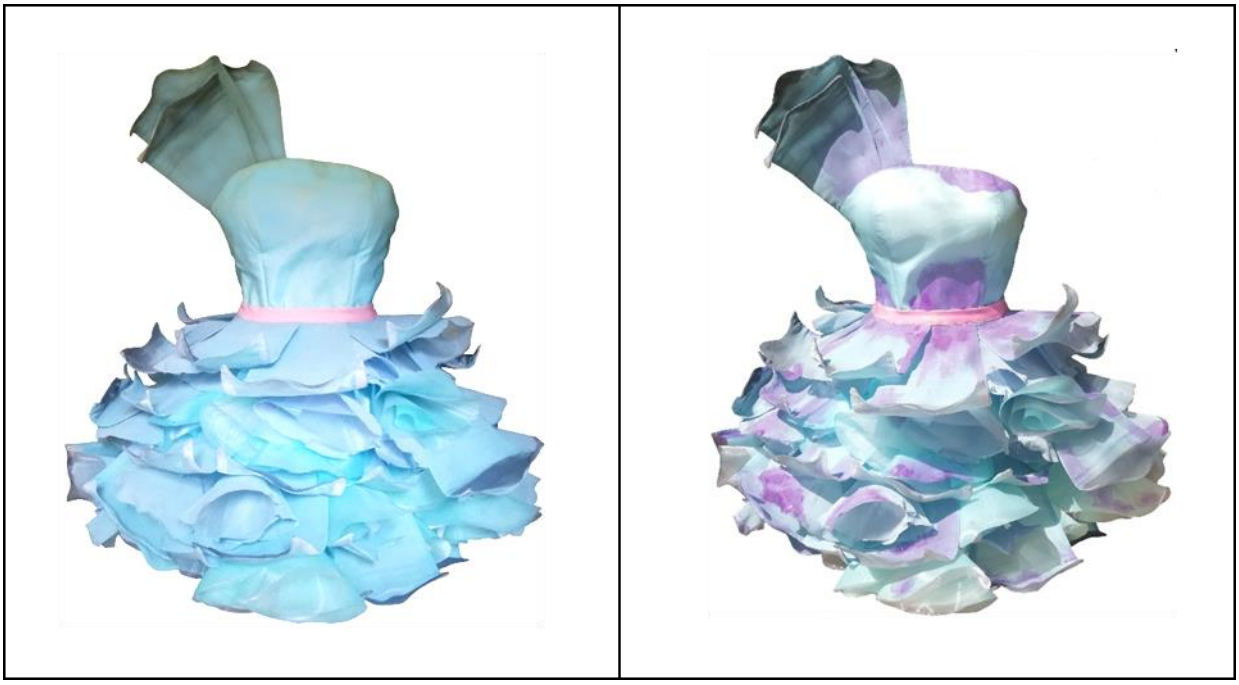
Although the traditional assessment standard is the use of a grayscale, yet in the case of thermochromic materials it has been stated in some researches that it is not appropriate to use it, cause of its dynamic change (19). Hence, the materials were compared while being wet and dry. In the case of colour fastness to crocking, when the materials were wet, when compared to

the grayscale, they were considered to be average while when dry, the thermochromic sample seemed to be better.

Designing Process

From each chameleon that has been analyzed, a combination of a source or two have been used together to design a Line in a collection. In Line 1, the main focus has been the tail and layering. The colour combination was inspired from a chameleon. In Line 1, Photochromic pigment has been applied on specific areas that are not in direct contact with the skin. This is due to its poor heat transmittance and air permeability. Figure.6 represents the Line of photochromic garments. The dashed red frame is the dress that has been executed. Figure.7 shows the executed dress which is made out of organza, chiffon, tulle, cotton, boning and Vilene. Figure.7 demonstrates the dress in both states, when it's not exposed to sunlight and after exposure to sunlight. It has been noticed that it takes an average of two seconds to transition from colourless to the purple colour when exposed to sunlight.

Figure.6 Line of photochromic garments inspired from the chameleon and colour palette.



Photochromic painted dress – No exposure to light. **Photochromic painted dress – Exposure to light.**

In line 2, the main sources of inspiration were the fins and the texture of a chameleon's skin. The colours as well were inspired from a chameleon. In this line thermochromic pigment was applied on the edges of the shoulders. Figure.8 is the line that represents thermochromic garments. Figure.9 demonstrates the executed top which is made out of satin. The transition time of the colour to colourless differed and that is due to the amount of heat that it gets exposed to. The higher the temperature that comes in contact with it the faster its transitions.

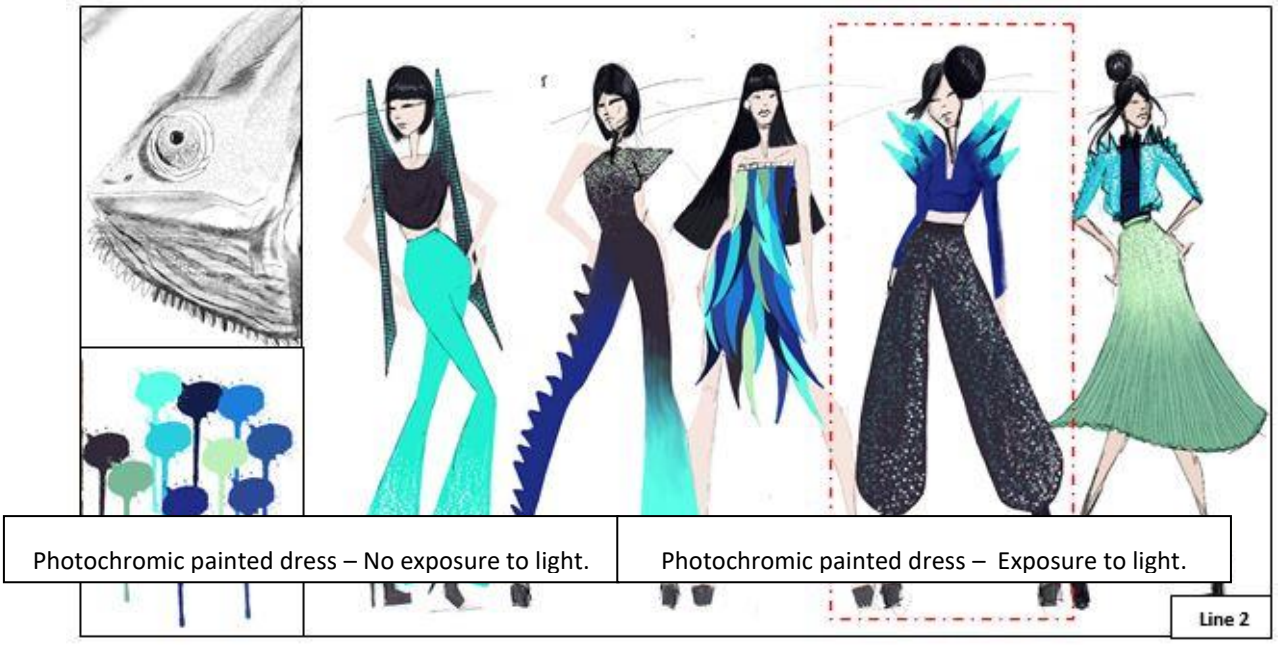
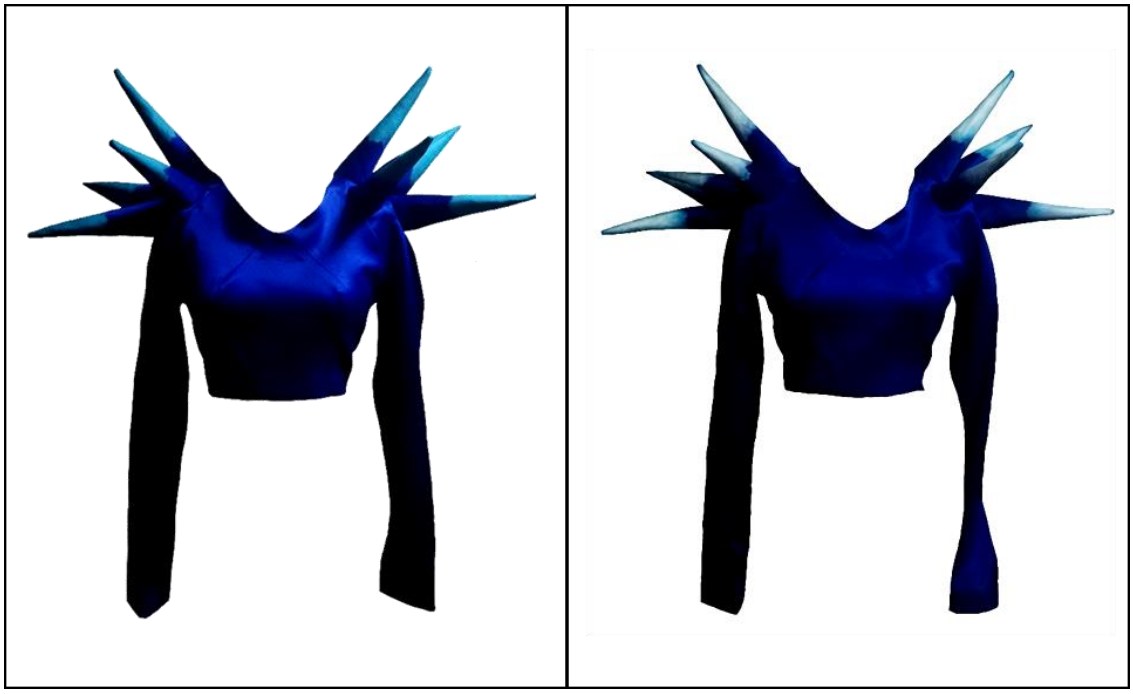


Figure.8 Line of photochromic garments inspired from the chameleon and colour palette.



Thermochromic painted top – No exposure to heat **Thermochromic painted top – exposure to heat**

Figure.9 Executed Top from the Thermochromic line.

Conclusion

In this era, innovative dyes and pigments have become a matter of interest to the majority of people. Thermochromic and photochromic dyes and pigments occupy a large amount of people but it is still considered to be a challenge since further understanding of the materials and the appropriate approaches needs to be further tested and developed. Multidisciplinary is recommended since it offers changes in the appearance of a garment but it is advised to use it in areas that are not in direct contact with the skin. More studies are recommended to be executed to improve the comfort of fabric.

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