EMERGING TRENDS IN ADAPTABLE TECHNICAL TEXTILE TECHNOLOGIES: OVERVIEW

Gopika K[1], Yuvasri N[2] , Dr.V. Krishnaveni[3]

[1&2]B. Tech Scholar, Department of Fashion Technology, Kumaraguru College of Technology, Coimbatore, Tamilnadu,India.

[3]Associate professor, Departme nt of Fashion Technology, Kumaraguru College of Technology, Coimbatore, Tamilnadu,India

ABSTRACT

Colour-adaptive clothing refers to garments that change colour in response to environmental stimuli. These garments incorporate advanced fibre coatings with unique optical, magnetic, and electrical properties, which are being extensively researched for both military and commercial applications. Among the most promising innovations are chameleon-like, colour-responsive fibre systems, expected to see widespread use in the near future. These smart materials are used in a variety of products, including sportswear, military uniforms, fashion garments, cosmetics, umbrellas, and even medical equipment. Colour-adaptive textiles respond autonomously to changes in environmental conditions such as temperature, light, pH levels, and electrical or magnetic fields. One of the most widely used technologies in this field involves thermochromic dyes. To date, twenty thermochromic dyes have been developed, many of which use crystal violet lactone as the primary colour-forming compound, with the colour intensity and responsiveness varying based on dye concentration and formulation.

Key words: Colour adaptation, chameleon effect, special textile.

1.INTRODUCTION:

In today's rapidly evolving world, emerging technologies are significantly influencing the fashion industry. One of the most remarkable developments is the integration of colour innovations and colour-responsive technologies, which are creating a dynamic shift in the way fashion is perceived and experienced.

Among these innovations, intelligent textiles have gained notable attention. These are advanced garments capable of responding autonomously to environmental changes such as temperature, light, pH levels, and electrical or magnetic stimuli. Their ability to adapt in real time enhances both functionality and aesthetic appeal, making them highly valuable in various sectors including fashion, sportswear, and healthcare.

1.1 Key Methods for Producing Intelligent Textiles:

- pH-induced changes
- Oxidation state modifications
- Molecular bond breaking or formation
- Mechanochromism – colour change through mechanical stress
- Electrochromism and magnetochromism
- Thermochromic composites
- Advanced weaving techniques

1.2 Key Factors Influencing Colour Adaptation:

- Changes in **oxidation states**
- **Bond breaking or formation** at the molecular level
- **Mechanochromism** – colour change due to mechanical stress

- **Electrochromism and magnetochromism** – triggered by electric or magnetic fields
- **Thermochromic composites** – sensitive to temperature variations

Among these methods, thermochromic composites and innovative weaving techniques are the most widely used due to their relative ease of implementation and broad commercial applicability. These techniques enable designers to create garments that not only look stylish but also respond to environmental stimuli, marking a revolutionary step in the fusion of technology and fashion.

2.THERMOCHROMIC COMPOSITES:

Chromic materials, often referred to as chameleon fibres, possess the remarkable ability to change colour in response to various external stimuli. Initially popularized in the fashion industry for creating visually engaging, colour-changing effects, these materials were once viewed as a fleeting trend. However, ongoing advancements in durability, accuracy, and responsiveness have significantly enhanced their potential for long-term, functional applications.

The term "chromic" originates from the Greek word for colour and refers broadly to materials that emit, erase, or alter colour when stimulated by environmental factors. These stimuli may include changes in temperature, light, pH, mechanical stress, or electric and magnetic fields.

A key category within this group is thermochromic materials, where heat acts as the external stimulus, causing the material to change colour based on temperature fluctuations. [2]. Thermochromic systems are now widely explored for use in textiles, packaging, and smart devices due to their dynamic and reversible nature.

Leuco dye-based thermochromic (TC) systems are widely utilized for their ability to undergo temperature-induced colour changes, finding broad application in smart packaging, security printing, textile coloration, toys, and marketing materials. These systems can be incorporated in several ways: encapsulated within a polymer envelope, deposited as pigments in polymer matrices, or directly integrated into polymer fibres and foils. [1].

A typical leuco dye-based TC system consists of **three main components**:

1. **Colour Former** – an electron-donating dye
2. **Developer** – a proton donor/electron acceptor
3. **Co-solvent** – a medium that facilitates phase change

At temperatures below the co-solvent's melting point, the colour former and developer form a coloured complex. When the co-solvent melts, this complex dissociates, rendering the system colourless. The melting point of the co-solvent usually defines the temperature at which the colour change occurs, though in some systems, decolouration may begin even before this point is reached.

This reversible colour transformation is characterized by the following terms:

- Switching temperature
- Discolouration temperature
- Thermochromic temperature
- Clearing temperature
- Activation temperature

Thermochromic behaviour typically exhibits a sigmoidal (S-shaped) temperature dependence, and the process involves colour hysteresis—a phenomenon where the colour change upon heating differs from that during cooling. These reversible effects have been well-documented in both commercial thermochromic inks and bulk TC systems, affirming their practical utility and responsiveness.

2.1 Mechanism and Evaluation of Leuco Dye-Based Thermochromic Systems

In leuco dye-based thermochromic (TC) systems, the colour former plays a crucial role as an electron-donating compound, commonly consisting of spirolactones, fluorenes, or spiropyrans. Among these, crystal violet lactone is the most widely used in research and commercial applications due to its reliable and reversible colour-changing properties.

The developer, on the other hand, acts as an electron acceptor or proton donor, and typically includes compounds such as:

- Bisphenol A
- Alkyl gallates
- Phenols
- Hydroxybenzoates
- Hydroxycoumarins

The third essential component is the co-solvent, which is often a long-chain alkyl alcohol, ester, or acid. This component influences the temperature at which the colour change occurs by determining the melting point of the system.

2.2 Colour Change Mechanism

In its inactive (colourless) state, the colour former exists in a closed lactone ring structure. Upon stimulation—either through protonation or an increase in the polarity of the surrounding environment—the lactone ring opens, initiating a colour change. This process is reversible, allowing the system to return to its original state upon cooling or stimulus removal.

2.3 Evaluation Methods

To quantitatively evaluate TC composites, several analytical techniques are employed:

- Characteristic wavelength reflectance ($R\lambda$): Often measured in solid-state or bulk systems.
- Colour density vs. temperature: Used to track the intensity of colour change with varying thermal input.

For practical testing, TC materials are often incorporated into substrates such as:

- Coated polyester films
- Impregnated filter paper
- Standard printer paper

These carriers provide a stable medium for measuring thermal response and evaluating performance.

2.4 Colorimetric Analysis

Extensive colorimetric studies, such as those by Kulčar et al., utilized reflectance spectra from commercial thermochromic inks to derive colour parameters within the CIELAB colour space. Parameters studied include:

- Lightness (L^*)
- Chromatic coordinates (a^*, b^*)
- Colour difference (ΔE) between heated and cooled states

From these analyses, four critical temperatures were identified:

1. Onset of decolouration (heating)
2. Completion of decolouration (heating)
3. Onset of colouration (cooling)
4. Completion of colouration (cooling)

These points help characterize the hysteresis loop, which represents the thermal range over which colour change occurs.(2) The area of the hysteresis loop and maximum decolouration rate were also calculated to assess responsiveness and reversibility.

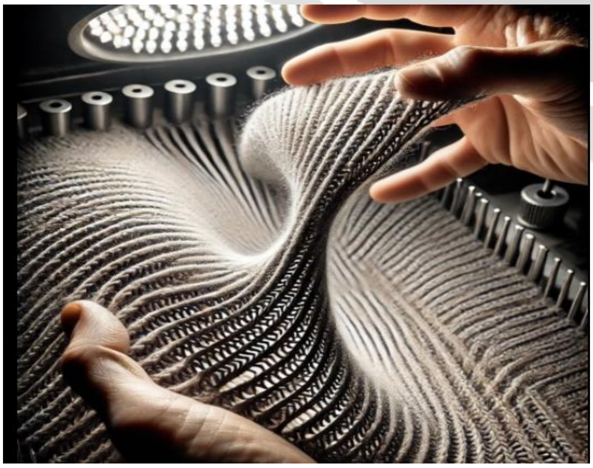
3.WEAVE BASED CHAMELEON EFFECT:

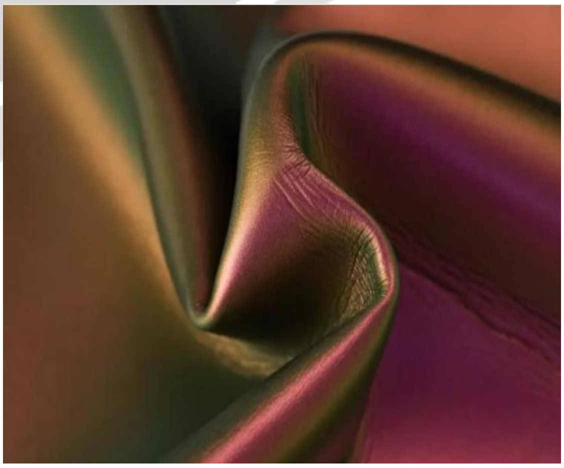
Punkto is a distinctive twill-woven curtain fabric designed by renowned Spanish architect and designer Patricia Urquiola for the Danish textile brand Kvadrat. Known for its soft and inviting texture, Punkto evokes the feel of fine cotton upholstery, offering both visual appeal and tactile comfort.(3)

Patricia Urquiola's inspiration for Punkto stemmed from her earlier work on the Relate and Reflect collections for Kvadrat. Both collections were known for their distinctive diagonal twill weave, a design language that continues in Punkto. While Relate was crafted from Trevira CS and Reflect from recycled polyester, both were conceived as "twin collections" — unified by their soft textures, designed to be gentle on both the skin and the eye.

In these earlier fabrics, two yarns were densely woven to give the textile a solid, sculpted appearance, almost as if it had been carved from a single material.

Expanding on this foundation, Punkto introduces an innovative approach by incorporating three contrasting yarns: one for the warp and two for the weft. This unique combination produces a rich, iridescent effect, where the fabric subtly shifts in appearance based on the intensity and angle of light. As Urquiola describes, the woven material "creates a kind of chameleon effect," offering a dynamic and ever-changing visual experience. [3,4].





4.METHOD OF PRODUCING PHOTCHROMIC EFFECT FABRICS:

The primary technical challenge addressed by the present invention is to develop a novel chameleon fibre garment material that is lightweight, resistant to high temperatures, soft, comfortable, and can be manufactured using an efficient production process.(5)

For solving the problems of the technologies described above, the invention provides a kind of manufacture craft of chameleon fibre garment material, comprising the following steps:

(1) choose photochromic dyes monomer, be made into particulate,

(2) above-mentioned particulate is mixed as sandwich layer with thermoplastic resin,

(3) general fibre is chosen as cortex,

(4) by above-mentioned (2) sandwich layer and last time cortex melt spinning altogether, obtain photosensitive colour-changing core-skin composite fibre,

(5) above-mentioned photosensitive colour-changing core-skin composite fibre is woven, obtain chameleon fibre garment material.(7)

In a preferred embodiment of the present invention, described thermoplastic resin comprises the polymer such as polyester, polypropylene, polyamide.

A manufacture craft for chameleon fibre garment material, comprises the following steps:

(1) choose photochromic dyes monomer, be made into particulate,

(2) above-mentioned particulate is mixed as sandwich layer with thermoplastic resin,

(3) general fibre is chosen as cortex,

(4) by above-mentioned (2) sandwich layer and last time cortex melt spinning altogether, obtain photosensitive colour-changing core-skin composite fibre,

(5) above-mentioned photosensitive colour-changing core-skin composite fibre is woven, obtain chameleon fibre garment material.

Additionally, the photochromic dye monomers used can include diarylethene and azobenzene, which are known for their excellent sensitivity, fatigue resistance, and reversible color change. These dyes also offer advantages such as high storage density and non-destructive information reading.(5,6,)

Furthermore, the thermoplastic resin may consist of polymers such as polyester, polypropylene, and polyamide.

Moreover, the general fibers can be selected from conventional options like cotton fiber, bamboo-carbon fiber, and synthetic fibers, providing the fabric with a comfortable softness and good wash resistance.[8]

4.CONCLUSION:

The colour-changing clothing has significant potential applications in defence, particularly for military personnel and intelligence agencies. Additionally, these garments appeal strongly to children and pre-teens due to their engaging and dynamic appearance. Currently, production of these garments is not highly sustainable, so they are typically produced as limited-edition items or for specialized functional uses. The chameleonic effect represents an advanced approach to aesthetic textile design. With further improvements in manufacturing techniques, this type of fabric could soon find broader applications in areas such as sportswear, health monitoring, and defence applications. While not yet suitable for mass production, advancements in sustainability and production efficiency may change this outlook in the near future.

5. REFERENCES

[1] Wang Haiying, Liu Guodan, Hu Songtao, Liu Chao, Experimental investigation about thermal effect of colour on thermal sensation and comfort, Energy and Buildings, Volume 173, 15 August 2018, Pages 710-718.

[2] Ondrej Panák, Markéta Držková [1], Marie Kaplanová, Insight into the evaluation of colour changes of leuco dye based thermochromic systems as a function of temperature, Dyes and Pigments,Volume 120, September 2015, Pages 279-287

[3]Metka Hajzeri [a], Kristina Bašnec [b], Marjan Bele [a], Marta Klanjšek Gunde,Influence of developer on structural, optical and thermal properties of a benzofluoran-based thermochromic composite, Dyes and Pigments,Volume 113, February 2015, Pages 754-762

[4]Rahela Kulčar [a], Mojca Friškovec [b], Nina Hauptman [c], Alenka Vesel [d], Marta Klanjšek Gunde, Colorimetric properties of reversible thermochromic printing inks, Dyes and Pigments,Volume 86, Issue 3, August 2010, Pages 271-277

[5] C.F. Zhu, A.B. Wu, Studies on the synthesis and thermochromic properties of crystal violet lactone and its reversible thermochromic complexes, Thermochimica Acta, Volume 425, Issues 1–2, 20 January 2005, Pages 7-12

[6] N Gobi , P. Sudhakar, Chameleonic Textiles – Only The Colours Change, www.fibre2fashion.com/industry-article

[7] P Leitch et al: New Material in New Millennium, Journal of Industrial Textile 2000, 29 (3), 173 191.

[8] Almas Sadique.Patricia Urquiola's latest fabric for Kvadrat adopts a chameleon effect, 2022