Journal of Textiles, Coloration and Polymer Science
https://jtcps.journals.ekb.eg/
Egyptian Society for Textile Science and Technology
الجمعية المصرية لعلوم وتكنولوجيا النسيج

Flexible Chromic Fabrics for Several Textile Applications

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Abstract

The research provides a brief overview of chromic materials and their applications in technical textiles. The major types of chromic materials are photochromic, ionochromic, thermochromic, and electrochromic materials, which can change color in response to different external stimuli. To illustrate the significance of ongoing research on high-performance textiles, the article reviews the main chromic materials and their corresponding textile applications.

Keywords: photochromic, ionochromic, thermochromic, electrochromic, fabric.

Introduction

Due to the numerous uses that are being found for chromic materials, smart textiles have recently undergone rapid growth. [1]

The Greek word "chromo" means "color," and it is used to describe color. A chromogen is a pigmented substance that has a chromophore within that produces the color. A chromophore is a group of atoms contained within a larger molecule that selectively absorbs certain visible light wavelengths while transmitting other wavelengths. [2]

This includes molecule-level modifications including chemical bond breaking and molecular conformation changes [3]

The addition of smart textiles into garments is nothing more than a reflection of modern human lifestyles that include access to technologically advanced, adaptable, and multipurpose things that are technologically advanced, adaptable, and multipurpose. Smart textiles may be used for a variety of purposes, including power production and storage, personal safety, sports, fashion, communication, and Internet of Things applications. [4-8]

Smart textiles are items that can both receive and respond to external stimuli to adapt to changes in their environment. These substances may respond to various physical stimuli, such as light, pH, Table 1 : classes of Chromism types. temperature, solvents with various polarity, chemicals, and electricity, and as a result, they can interact with their surroundings (sense, respond, communicate, and adapt). With environment [9-23]

Three categories of smart textiles can be distinguished: (1) passive smart textiles, which only use sensors to sense their surroundings and users; (2) active smart textiles, which combine an actuator function with a sensing device to respond to environmental stimuli; and (3) very smart textiles, which can sense, react, and modify their behavior in response to the environment

Chromism is the phenomenon of reversible color change that results from a change in the electron density of substances or a rearrangement of the supramolecular structure of the same substances. This indicates that the occurrences are brought about by a variety of stimuli capable of changing the electronic density of the molecule or material, including the "pi" and "de" electron positions.

Classes of chromism types

Chromism is a term used to describe the phenomenon where the color of a substance changes in response to an external stimulus. There are different types of chromism, including photochromic, thermochromic, electrochromic, solvatochromic, halochromic, acid chromic, and ionochromic.

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Receive Date: 19 July 2023, **Accept Date:** 06 August 2023
DOI: 10.21608/JTCPS.2023.224022.1234

Chromism type	External stimulus
Photochromic	Light
Halochromic	Ph
Thermochromic	Heat
Electrochromic	Electric current
Mechanochromic	Mechanical deformation
Piezochromic	Mechanical pressure
Tribochromic	Mechanical friction
Solavtochromic	Solvent polarity
Hygrochromic	interaction with bulk water or humidity
Chemochromic	Chemical agents
Ionochromic	Ions
Chronochromic	Time
Gasochromic	a gas—hydrogen/ oxygen redox.
Carsolchromic	Electron beam
Vapochromic	the vapor of an organic compound due to chemical polarity/polarization
Biochromic	Biological agents
Aggregachromic	dimerization/aggregation of chromophores.
Crystallochromic	Crystal structure change of a colorant
Magnetochromic	Magnetic field
Cathodochromic	Electron beam irradiation
Radiochromic	Ionizing radiation

These chromic processes are induced by heat, light, electricity, ions, or other external factors. The compounds responsible for these transitions are capable of absorbing different wavelengths of light. Figure 1 illustrates the different types of chromism and their causes. Smart textiles can exhibit chromic effects through various mechanisms.

In addition to the individual types of chromism, there are also mixed chromisms that involve two or more stimuli. Examples of these mixed chromisms include photo electrochromism, photovoltachromism, electrochromism, solvatophotochromism, thermos-olvatochromism, halosolvatochromism, electro-mechanochromism, and others.Photochromic textiles :

Photochromic fabrics can undergo reversible color changes when exposed to electromagnetic stimulation. To achieve this, traditional dyeing methods can be used to incorporate photochromic molecules into fibers or textile surfaces can be coated with microcapsules containing photochromic [24]. These photochromic materials are classified as either T-type or P-type, depending on whether the reverse reaction occurs thermally (T) or photochemically (P). The most commonly used photochromic dyes include spiropyrans, spirooxazines, naphthopyrans, diaryltenenes, fulgids, and azobenzenes. Spiropyrans, spirooxazines, naftopyrans, and azobenzenes are the most popular T-type photochromic materials used in the textile industry and are sensitive to heat influences. Diarylenes and fulgids are examples of P-type photochromic materials that are thermally stable. [25] developed a spirooxazine material with photochromic properties and used it to create woolen fabric with excellent photochromic properties, fast decolorization time, strong fatigue resistance, and good washing stability and shrinkage performance (see Figure 1).

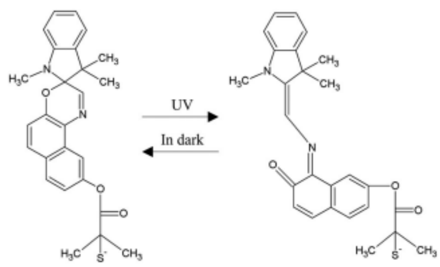

Fig 1: Color change mechanism of photochromic fabric [25]

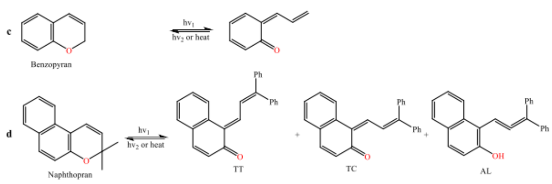

Fig 2: Photochromism of (c) benzopyran, and (d) naphthopyran.

Under UV irradiation, the chemical structure of spiroxazine undergoes a color change from a closed loop to an open loop. In the absence of UV light, the color returns to the original state from the open loop recovery into a closed loop, which is the basic principle behind the photochromic phenomenon. When exposed to UV light, the photochromic compound decolorizes because the photoproducts absorb at lower wavelengths than the original compound.

The photochromic compound is colored until it is exposed to UV light

Mechanism of photochromic

Over time, various families of photochromic dyes (PDs) have been developed, differing mainly in the type of photochemical reaction that causes the color change. PDs can be classified based on their photoreaction route, which includes trans-cis isomerization (as shown in Figure 3), photocleavage of bonds (as shown in Figure 4), electrocyclization and cycloreversion reactions (as shown in Figure 5), and intermolecular cycloaddition and cycloreversion reactions (as shown in Figure 6). [26]

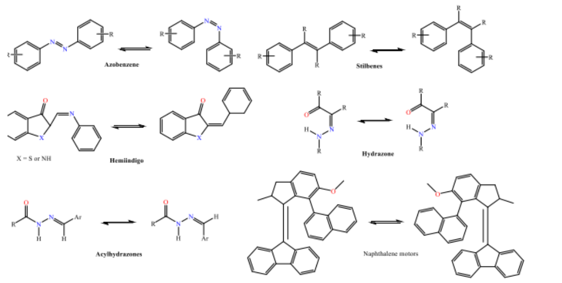

Fig. 3. Trans-cis isomerization type photo dyes

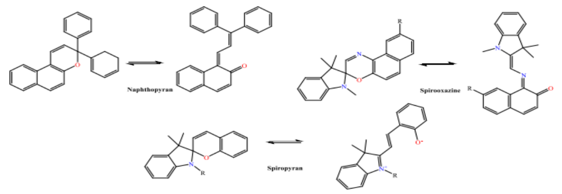

Fig. 4. Csp3-pyranAO bond photocleavage type of photochromic dyes

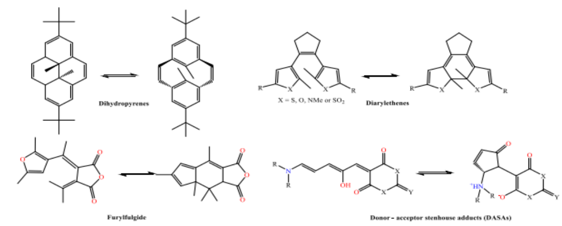

Fig. 5. Electrocyclization and cycloreversion reaction type of photochromic dyes

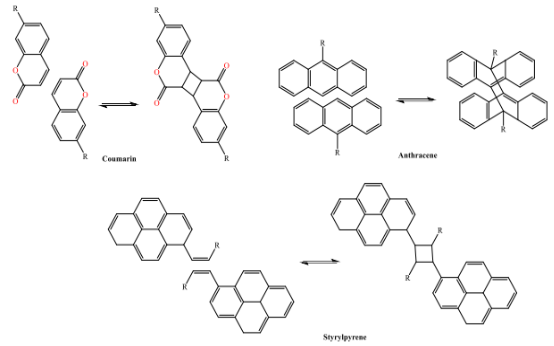

Fig. 6. Intermolecular cycloaddition and cycloreversion reactions type of photochromic dyes

Binder film production is a common method of attaching photochromic molecules to the surface of textiles. photochromic cotton textiles by applying photochromic microcapsules onto the fabric. the study used polydimethylsiloxane to attach pre-prepared photochromic microcapsules to cotton fabric. However, the use of additional binders in printing photochromic compounds on textiles has led to issues such as poor washability and a stiff texture. To address these problems, chemical linkages between textiles and photochromic molecules can be used. The study described techniques for producing durable and photochromic cotton-based materials using click chemistry to form covalent bonds between photochromic chemicals and cotton fibers.

Application of photochromic textiles

1. Textiles can be made to provide both UV protection and color-changing effects. Optical brightening textiles can improve UV protection by converting UV light into blue fluorescence, while encapsulated spirooxazine-based photochromic dyes applied to cotton textiles can also increase UV protection.
2. Photochromic materials can be used to design military protective apparel with camouflage patterns that change color to match the surrounding environment when exposed to sunlight. The use of photochromism in textiles presents creative opportunities for creating smart clothing that can block UV radiation, sense environmental changes, print security, protect brands, and provide sportswear, fashionable clothing, and clothing for special services such as police and fire brigades. It can also create fabric-based electronic image displays, security barcodes, sensor systems, solar heat management, lighting control, and eye-catching decorations. [27]
3. A unique type of SMART photochromic fabric can be produced by covalently joining cotton fabric modified with 3-mercaptopropyl trimethoxy silane (MPTMS) and spirooxazine

(SO) using the thiol-ene click chemistry method. The optical properties of the fabric can be dynamically modulated, and it can change from colorless to blue under UV irradiation with a short reaction time, showing clear images. The photochromic fabric is reusable after 20 reversible color-changing cycles and has considerable usefulness in SMART devices and light sensing. [27]

4. Photochromic silicon dioxide nanoparticles can be inserted into cotton fabrics using screen printing and dispersed in aqueous acrylics and polyurethanes. All fabrics displayed reversible photochromism under UV and solar light, responding quickly and vividly. [28] utilized UV-responsive silica phosphomolybdate nanoparticles to create photochromic materials for textiles.

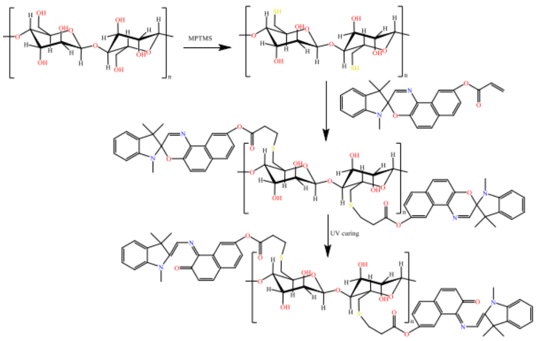

Fig 7: Schematic diagram of the preparation process and photochromic mechanism of photochromic cotton fabric

Electrochromic textiles

Electrical potential can alter the color of electrochromic textiles, which occurs due to the formation of visible electronic absorption bands when switching between redox states. This process, which involves the gain or loss of electrons, affects the optical properties of the fabric and can be achieved with a low voltage. The color change is persistent and can be reversed by applying an inverted potential. Electrochromic wearable technology represents one example of integrating new features with conventional materials. [29]

Typically, inorganic substances such as tungsten oxide, metal phthalocyanines, and Prussian Blue are commonly used as electrochromic colorants.[29] , [30]When tungsten(VI) oxide is partially reduced to tungsten(V) oxide at a cathode, the color of pure tungsten oxide changes electrochemically from pale yellow to blue Methyl viologen[29] (Fig. 12) is a well-known example of an electrochromic colorant. It is made up of colorless bipyridylium dication and can introduce blue radical cation through a reduction process at a cathode [31] Thiazines and 1,4-phenylenediamines are two more organic electrochromic colorants that are readily accessible. [32, 33] Additionally, the creation of electrochromic polymers like polyanilines and polythiophenes has attracted attention.

Types of electrochromic materials

A significant portion of economically important electrochromic materials are made up of inorganic substances. Many transition metal oxides, such as tungsten oxide (WO3), exhibit electrochromism, with WO3 being the most notable. Other examples of inorganic electrochromes include Prussian Blue, related metal hexacyanoferrates, and specific metal phthalocyanines, which all display electrochromism in their solid state. In the case of WO3, the pure compound is pale yellow, but in a thin film, it appears almost colorless. The electrochemical process of partially reducing W(VI) to W(V) at a cathode causes the blue color to appear, with the intensity of the color being directly proportional to the amount of charge injected.

Methyl viologen is the most well-known example of a substance that exhibits electrochromism in a solution. The colorless bipyridylium dication undergoes reduction at a cathode to form the vivid blue radical cation shown in Fig. (8). Other organic electrochromes include 1,4-phenylenediamines (Wurster's salts) and thiazines. Recent advancements have also been made in polymeric electrochromic materials, including specific derivatives of polyaniline and polythiophene.

Fig. 8. Electrochromic behavior of methyl viologen

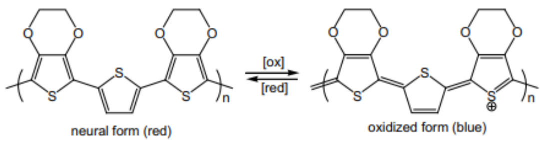

Fig. 9. Chemical structure of poly(3,4-ethylene dioxythiophene)

Electrochromic material

As previously stated, electrochromism is a phenomenon where certain materials undergo a reversible color change when an electrical potential is applied. This color change occurs when the electrochromic material is either oxidized or reduced, resulting in a change in its band gap that is driven by a corresponding change in the electrical potential. Synthetic chemistry has the potential to produce a wide range of electrochromic materials.

Organic electrochromic materials are a significant class of materials used in electrochromic devices and can be categorized into three groups:

a) Type I electrochromic materials may be dissolved in reduced and oxidized states; and is always in solution when used for electrochromic purposes (for example, a methyl viologen becomes bright blue when reduced on an electrode). [34]
b) Type II electrochromic materials, which are soluble in one redox state but solidify on the surface of an electrode during electron transfer (for example, heptyl or benzyl viologens, three redox states of this type of viologen are shown in Scheme 10, where the dicationic state is most stable and the solid form of 1,1'-di-n-heptyl4,4'-bipyridilium (heptyl) [35], [36]
c) Materials of class III electrochromics, which are often conducting polymers. Numerous applications, including electrochromic color change in textiles and display applications, are hopeful candidates for the intrinsically conducting and electrochemically active properties of most these types of polymers. [36]

Production of electrochromic textiles can make use of viologens, conjugated electrochromic polymers, and compounds based on metal oxides. Conjugated electrochromic polymers, however, are being sought after more and more as a result of their numerous practical benefits over competing materials.

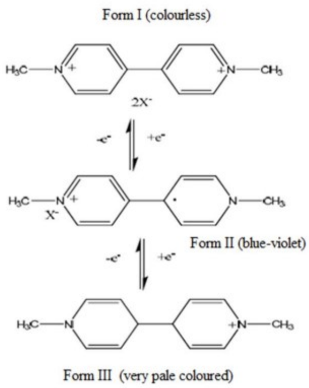

Fig. 10. A schematic representation of three common redox states of a viologen (where form I is colorless, form II is blue-violet and form III shows very little coloration)

Application Electrochromism in Textiles

Electrochromic fabrics have diverse applications such as biomimicry, flexible displays, and camouflage. However, there are substantial engineering obstacles in developing electrochromic devices based on textiles that are flexible and stretchable [37]. A notable prototype of electrochromic clothing has been developed recently, which involves incorporating electrodes into spandex fabric that has been treated with an electroactive polymer called poly(3,4-ethylene dioxythiophene)/ poly(styrene sulfonate). The substrate was combined with a transparent organogel electrolyte, while one of the electrodes was coated with a polythiophene derivative to act as an electrochromic polymer. [38] [39]. The electrochromic device made from textile material is capable of switching between the colors red and blue. This experimental device is a crucial initial phase in the creation of highly advanced, controllable, and adaptable clothing. However, there are several technological and commercial challenges associated with electrochromic textiles, such as connectivity and textile integration, lack of standards and interoperability, and complexity of the products. The study demonstrated the use of dichroic dye-doped liquid crystal microcapsules, prepared through emulsion polymerization, and investigated their ability to prevent discoloration when incorporated into textiles. The researchers found that the textiles changed from red to transparent when an electrical voltage was applied or removed, indicating their potential for use in various applications of smart fabrics. [40]

The study demonstrated that wool fabrics can possess excellent flexibility and electrochromic properties. The foundation for the textiles was made up of indium tin oxide (ITO) or platinum (Pt) and tungsten oxide film layers. The researchers found that the wool with a Pt layer exhibited the highest reversibility efficiency when lithium was intercalated using the radio frequency magnetron sputtering technique. Wool containing ITO displayed a superior color change, which was attributed to the transparency of its structure and the preservation of the wool's natural color. [37]

Recently, electrochromic supercapacitors have been under review due to the increasing demand for portable and interconnected devices that are as visually appealing as they are functional. The development of electrochromic textiles presents a challenge in maintaining comfort and high performance while incorporating the necessary electrochromic chemicals into the fabric. Addressing these issues requires large-scale production, washability, and user acceptability of the smart electrochromic textile technique.

Ionochromic textiles

Ionochromic fabrics undergo a color change by altering the emission or absorption spectra of molecules due to the interaction of ionic species. There is limited research on the use of ionochromic technology in textiles, with only one research paper found in the literature. This paper describes a type of

Fe(II)-ion sensitive cloth that exhibits ionochromism and can change color. [41]

Ionochromisim

Ionochromism, which is a reversible color change brought on by the addition of ions, is very comparable to halochromism, which is a color change brought on by a shift in the pH of the environment. Ionochromic materials are those that exhibit these kinds of color variations. It is significant to note that the phrases halochromic or pH sensitive are frequently employed when the predominant ionic species is the solvated hydrogen ion. Other forms of ions are also created by this class of materials, with metal ions and onium cations (such as tertiary ammonium and phosphonium) being two of the most often seen ions. The typical reversible [42] color shift in this situation is from an uncolored state to a colored state or from one colored state to another colored one.

Ionochromic materials come in a variety of forms, but among of the more significant ones include

(a) phthalides
(b) triarylmethanes
(c) fluorans.

These three groups comprise the majority of pH-sensitive dyes that are commercially available. The pH-sensitive natural dyes, some of which are referred to as anthocyanines, also exhibit potentially useful ionochromic forms.

Ionochromic materials can be applied to textiles in a variety of methods, including dyeing, printing, coating, extrusion, and microencapsulation. [43-45]

Ionochromisim dyes

The study utilized three different ionochromic dyes (PHE, EB-T, and XO) to color silk fabric and examined the color changes induced by the presence of Fe(II) solution. The authors observed a shift from white to red when Fe(II) solution was used to trigger the color change in silk fabric, but no change in color when Cu(II), Mg(II), or Ca(II) solution was used. The color variations were found to be affected by pH level, ion concentration, and reaction time. The researchers noted that ionochromic textiles have potential applications in bionic silk flowers, magic games, anti-counterfeiting materials, and Fe(II) detection.

PHE was found to be the best dye for use on silk fabric compared to cotton, nylon, and polyester. When PHE-dyed silk cloth was exposed to Fe(II) solution, a clear color shift from white to red was visible to the naked eye. The type of ion, pH level, ion concentration, and contact duration all influenced the color change. After 15 minutes of exposure to an 8 mg/l Fe(II) solution with a pH of 7-8, the ionochromic fabric exhibited a distinct color shift. Additionally, the colored ionochromic cloth dyed with PHE demonstrated a clear Fe(II)-sensitive color-changing effect. [41]

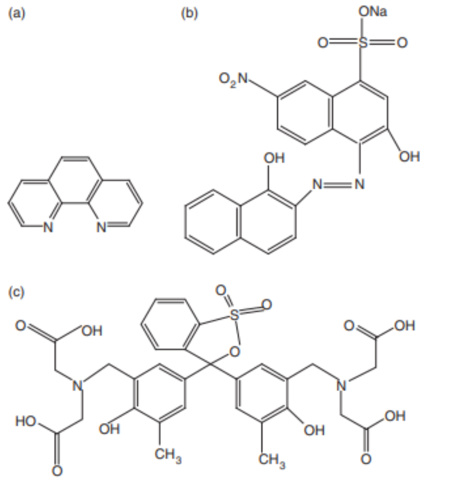

Fig. 10 Chemical structures of (a) PHE, (b) EB-T, and (c) XO

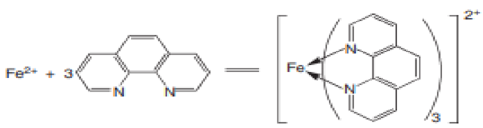 (1)

Fig. 11. formation of a ferrous phenanthroline complex, which is a red substance.

Classification and Method of Application

The phthaleins (which are often accessible in their lactone form, for example) and the sulfophthaleins are two classes of phthalides-based indicator dyes that change color in response to a change in the pH of the surrounding environment. Although very thorough studies are required to improve various technical performances (such as wash fastness, lightfastness, abrasion resistance, and perspiration resistance), several commercially available indicator dyes (such as phenol red and cresol red) can be used for the dyeing, printing, and coating of various types of textiles.

Application in Textile

Numerous significant real-world technical uses exist for ionochromic materials.

Ionochromic materials, such as synthetic indicator dyes or natural anthocyanines, can be used to create ionochromic fabrics. They are appropriate for a wide range of real-world uses, including

(a) the detection of poisonous gases
(b) the measurement of humidity
(c) the detection of poisonous metals
(d) the monitoring of functional decline.

When employed as hydrogels, ionogels, or similar other types of materials, they are also beneficial for various applications in healthcare textile goods when included in smart textiles along with other necessary relevant features. [44][45]

Thermochromic

A frequent reversible color shift brought on by either heating or cooling is known as thermochromism. Thermochromic materials may be categorized into two categories: intrinsic materials, where heat directly causes color change, and indirect materials, where heat causes changes in the environment surrounding a chromophore, which in turn impacts the chromophore and cause a color change. [46]

Classification

Inorganic Thermochromic

In solid or solution phases, a variety of inorganic compounds exhibit thermochromic color change. Several mechanisms for these molecules exhibit temperature-dependent thermochromic color changes, including:

(a) phase transitions
(b) changes in compound geometry
(c) equilibria between various molecular structures
(d) changes in the number of solvent molecules in the coordination sphere (for instance, dehydration).

Transition metals and organometallic compounds are the primary sources of inorganic thermochromic systems. Typically, inorganic thermochromic systems display inherent color changes that are dependent on heat. Examples of inorganic thermochromic compounds include:

(a) Cu2HgI4, which turns red at 200 degrees Celsius but turns black at 700 degrees Celsius,
(b) ZnO, which turns white at normal temperatures but yellow at higher temperatures, and
(c) In2O3, which turns yellow at low temperatures but yellow-brown at high temperatures. [47-49]

Organic Thermochromic

Organic thermochromic systems differ from inorganic thermochromic systems in that they exhibit reversible thermochromic color change, involving both intrinsic and indirect systems. This means that they change color when exposed to heat without external factors and return to their original form when cooled down after being removed from the heat source.

Organic thermochromic systems can be classified as reversible intrinsic thermochromic, and they use four main types of processes to explain the color change phenomena: molecular rearrangement, stereoisomerism, macromolecular systems, and supramolecular systems. These processes are typically employed to explain the color change phenomena in various thermochromic systems. [50]

The leuco class of thermochromic materials is widely used in industry due to its ability to be encapsulated in a composite. The color development of these materials is dependent on the reaction of three components: aliphatic alcohols, which serve as a low-melting/nonvolatile hydrophobic solvent, leuco dyestuff as an organic colorant, and a proton donor as an acid developer. [50] The leuco dye color former belongs to the spironolactone dye class and is a halochromic dye that is responsive to changes in pH [32][33]. Crystal violet lactone is a commonly used color former that is colorless in its ring-closed molecular state (as shown in Fig. 12). However when the pH is lowered, the molecule undergoes a ring-opening reaction and becomes a protonated form, resulting in a color change resulting in the creation of a reddish-blue color. When the temperature is raised, leuco-based thermochromic systems range from colored to colorless [51, 52].

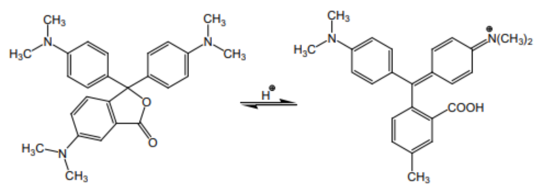

Fig. 12 Protonation of crystal violet lactone

Compared to the ring-closed species, this ring-opened molecular form has an extended higher conjugated molecular structure.

The second class of materials that may be used to create thermochromic textile goods is liquid crystals. They provide an always-shifting rainbow of colors at various temperatures. Commercial thermochromic products [53, 54] have been made using chiral nematic liquid crystalline homologs of esters (Fig. 13).

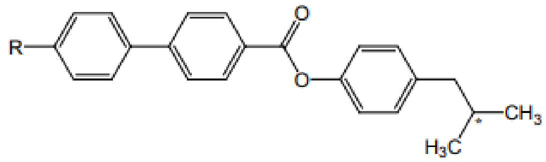

Fig. 13 Molecular structure of chiral nematic liquid crystal; * is an asymmetric center

The washability of printed textiles indicated a comparatively strong attachment of colors to the fabric surface, according to the authors.

Application in textiles

The thermochromic fabric has been utilized in biosensing applications, such as a dynamic thermochromic t-shirt with intricate designs that change color in response to the wearer's rising skin conductance levels, indicating sudden arousal. This phenomenon was investigated using the thermochromic t-shirt.. [3]

A thermochromic pigment applied to a specific area of cloth could potentially serve as a wearable and non-invasive method for early detection of fever in young children.[3]

The application of thermochromic pigments in textiles is currently restricted due to insufficient research on their ability to withstand external factors such as washing agents, sunlight exposure, higher ironing temperatures, and wear and tear. These factors may impact the effectiveness of the pigment in imparting thermochromism and temperature-adjustable properties to the fabric, thus affecting its durability and longevity. To develop more robust and enduring thermochromic textiles, further research is needed. [55]

The challenges were solved by using microencapsulation [56]

They developed a new method that utilizes thermochromic leuco dye-loaded silica nanocapsules to prepare color-changing polyester fabrics. The authors found that the excellent colorfastness of the fabrics was due to the crosslinking structures created by the silica nanocapsules among the fibers. [57]

The study focused on the development of reversible thermochromic microencapsulated phase change materials for use in thermal energy storage in thermal protective gear. The authors highlighted that these materials have significant potential for use in smart textiles due to their excellent performance in storing and releasing latent heat, reversible thermochromic properties, and stability. [58]

The study showed clothing with thermochromic pigments to sense physical tiredness.

The thermochromic results of using indigo dyes were discussed by [59] Thermochromic pigments were used in the finishing process of leather to produce leathers that changed colour with temperature.

The authors evaluated the technical characteristics of the materials and demonstrated the potential of these smart textiles for cutting-edge design concepts. [60] also looked at thermochromism for smart leathers.

The authors created a transition metal complex with rare earth doping that changed color between pale pink and dark green between 200 and 210 C. This colorant is intended to be used in safety items like heat-resistant gloves and may be applied to leather using standard finishing processes.

The following application fields have been identified as having potential by manufacturers: permanent fragrance insect repellents, cosmetics, dyes, antimicrobials, phase-change materials, fire retardants, anti-counterfeiting, polychromic and thermochromic effects, technical textiles, and specific medicinal applications [61]

Conclusion

The study showed that chromic materials have proven their efficiency in the textile industry. Photochromic dyes are used in providing textiles with UV protection as well as being utilized in making military garments' camouflage pattern. Electrochromic dyes are additionally used in various applications including biomimicry, flexible displays, and camouflage. Monochromatic materials have a wide range of applications as well. In real-world scenarios, chromic materials are applied in the detection of poisonous gases, measuring humidity, detecting poisonous metals, and monitoring functional decline. These materials can also be used as hydrogels, angels, or other types of materials, which are beneficial for various healthcare textile applications when incorporated into smart textiles along with other relevant features.

Thermochromic cloth has been used for biosensing applications. A dynamic thermochromic t-shirt with designs that change color based on the wearer's skin conductance was used to study abrupt arousal. Additionally, thermochromic pigment applied to a specific patch of cloth could be used as a non-invasive fever detection method for small children and others. In conclusion, chromic material proved their potential in altering textiles and imparting them with new features helping the life of the consumers a lot easier as well as widening the horizon of the textile industry specifically in protective clothes.

Conflicts of interest

There are no conflicts to declare

Funding sources

There is no fund to declare

Acknowledgments

The authors are gratefully-grateful to acknowledge the Faculty of Applied Arts, Benha University. Furthermore, the authors are gratefully grateful to acknowledge the Central Labs Services (CLS) and Centre of Excellence for Innovative Textiles Technology (CEITT) in Textile Research and Technology Institute (TRTI), National Research Centre (NRC) for the facilities provided.

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منسوجات كرومية مرنة تم تطويرها مؤخرا للعديد من تطبيقات النسيج

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الملخص

يقدم البحث لمحة موجزة عن المواد الكرومية وتطبيقاتها في المنسوجات التقنية. الأنواع الرئيسية للمواد الكرومية هي المواد الفوتوكرومية والأيونوكرومية والحرارية والكهروكرومية ، والتي يمكن أن تغير لونها استجابة للمحفزات الخارجية المختلفة. لتوضيح أهمية البحث المستمر حول المنسوجات عالية الأداء ، تستعرض المقالة المواد الكروم الرئيسية وتطبيقات النسيج المقابلة لها.

الكلمات الرئيسية: الفوتوكرومية ، الأيونوكرومية ، الحرارية ، الكهرومغناطيسية ، النسيج.