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Types of Chromism & Its Applications in Fashion & Textile Designing

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ABSTRACT

The main aim of this review paper is to give an overview about chromism & its various types. It also focuses on the application areas of chromic textiles in fashion industry. The main aim of this paper is to give knowledge of where these research technologies are today and also give a good overview of the stimuli- sensitive textiles/ environmentally sensitive textiles & materials that exist. The viewpoint is technical, leaving e.g. social changes, cultural references, economy and ergonomic aspects to other papers. [1]

Chromic colorants that change rapidly from colorless to colored state and colored to colorless state i.e. reversible when activated by stimuli like ultraviolet irradiation, temperature or pH. Use of chromic systems in applications like medical thermography, plastic strip thermometers, photochromic lenses, food packaging and non- destructive testing of engineered articles and electronic circuitry is well documented. However, in the last few years, the research on application of these systems on textiles has picked up significantly. This review paper presents a summary of the chromism phenomenon, types, chemistry, other technical features, current and potential application areas as well as challenges encountered in wider acceptance of chromic colorants on textile.[2]

INTRODUCTION
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Colour plays an extremely important role in our everyday lives. Obviously the main use of colour in technology is to impart a visual stimulus as part of the overall aesthetic of the object being viewed. [3] Chromic Materials are also called chameleon or chromeogenic materials, because they can change their colour according to external conditions. These materials have mostly been used in fashion, to create funny colour changing designs. [1] "Chromic" as suffix means reversible change of color and by extension, a reversible change of other physical properties. Chromic materials are engineered to sense and respond to external environmental conditions and stimuli. Thus, color changing technology offers unique and challenging design opportunities to the designer. [2] One of the properties of chromic materials is that they can radiate the colour, erase the colour or just change it. Chromic textile materials are to create fantasy designs. [4] Many materials are chromic, including inorganic and organic compounds and conducting polymers.

CHROMISM

Chromism can be stated as the phenomenon in which colour is the result of a broad spectral interactions among incident light and material (Bamfield 2001). [5] It is a process that induces a change (typically reversible, yet, it can be irreversible) in the colors of certain compounds resulting from a process caused by some form of stimulus. [6] Normally, chromic phenomena involve processes causing reversible colour change, absorption and reflection of light, absorption of energy and emission of light, absorption of light and energy transfer or a conversion and manipulation of light. [7] Several examples of chromic phenomena are already applied in everyday life, such as photochromic lenses for spectacles and thermochromic temperature indicators (e.g. in baby spoons). In addition, in the field of textiles, chromism has become an interesting area of research. [8] Normally, the change depends on the involvement of some stimuli. On the basis of the stimuli involved, chromism can be categorized in a variety of ways,

- Photochromism - change in colour of a compound is light induced, based on izomerization among two different molecular structures
- Thermochromism – change in colour of a compound is heat induced, most frequent form of chromism
- Electrochromism – change in colour of a compound is caused by an electrical current. Induced by the acceptance or donation of electrons.
- Solavtochromism – change in colour of a compound is caused by solvent polarity. Most of the solvatochromic compounds are metallic complexes
- Ionochromism – change in colour of a compound is ion induced
- Halochromism – change in colour of a compound is caused by change in pH
- Tribochromism – change in colour of a compound is mechanically induced (friction)
- Piezochromism – change in colour of a compound is mechanically induced (pressure)
- Mechanochromism – change in colour of a compound is induced by deformation(mechanical activity)
- Hygrochromism – change in colour of a compound is induced by presence of moisture
- Chemochromism – change in colour of a compound is induced by specific chemical agents i.e. toxic gasses, detergents etc.
- Vapochromism – change in colour of a compound is induced by vapors
- Chronochromism – change in colour of a compound is induced by time
- Radiochromism – change in colour of a compound is induced by ionizing radiation
- Magnetochromism – change in colour of a compound is induced by magnetic field
- Biochromism – change in colour of a compound is induced by biological sources
- Carsolchromic – change in colour of a compound is induced by electron beam. [7]& [5]

Chromism has been studied since before the 1900s and the main applications are in the areas of photochromism, thermochromism and electrochromism such as paints, inks, tiles, eyeglasses, windows and many optical applications. The most applied chromic solutions in textiles and fibre materials are the two first groups, photochromic and thermochromic. [9]
As far as quality of the chromic materials goes, it will depend on several parameters:

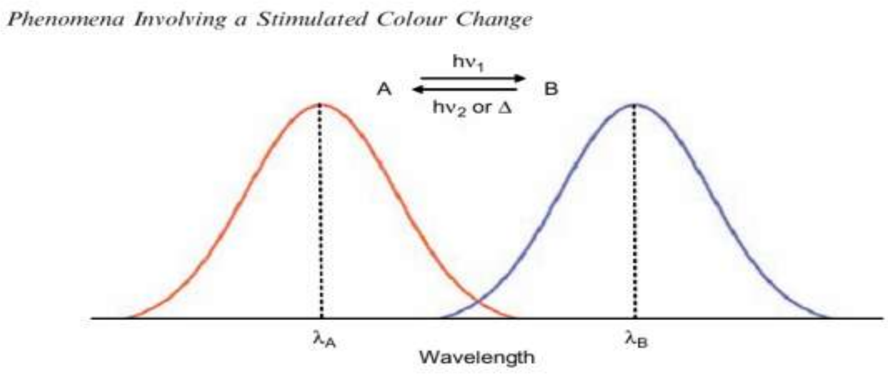
- Intensity of change in colouring of a compound
- Change in colouring
- Conditions of transition, change
- Dynamics of colour change
- Interval of change
- Simplicity of use
- Reversibility
- Number of colour change cycles it is capable of withstanding
- Fatigue resistance
- Fastness to heat, light, moisture (atmospheric conditions)
- Allergic reactions [5]

DIFFERENT TYPES OF CHROMISM:

1. Photochromism

Photochromism is a change in colour, usually colourless to coloured. Photochromism is a chemical process in which a compound undergoes a reversible change between two states having separate absorption spectra, i.e. different colors, whether the compound is in a crystalline, amorphous or solution state. The external stimuli energy is light, and the material or chemicals undergoing this change are photochromic.

The change, as illustrated, from a thermodynamically stable form A to B occurs under the influence of electromagnetic radiation, usually UV light, and in the reverse direction, B to A, by altering or removing the light source or alternatively by thermal means.



Reversible photochromism

When the back reaction occurs photo chemically this is known as type P photochromism (Eg: spiropyrans, spirooxazines and chromenes and when thermally as type T photo-chromism (Eg: fulgides and Diarylethenes). [3] Photochromism is of two types positive and negative. In Positive Photochromism the colorless substance converted in to colored object when exposed in to the light due to Uni-molecular reaction system. Bi molecular reaction system is called Negative Photochromism i.e. from colored to colorless. [10] Photo chromic dyes are dispersing dyes. Applying these dyes to natural fibers, such as wool, cotton, and silk, usually results in poor washing fastness. A T-shirt made of photochromic prompted fabric was introduced in the market in 1989. [11]

Applications of Photochromic Materials

Besides the well-established use of photochromic materials in ophthalmic lenses, especially in plastic lenses for sunglasses that darken when exposed to strong sunlight and reverse back to colourless in low-light situations, such as indoors, & camouflage fabrics offer the wearer personal comfort and safety. Typical uses for photochromic effects are on children's toys and for logos on T-shirts, lunch boxes, crayons, jelly shoes, hair clips, hair combs, shoe laces, coasters, craft beads, PVC belts, watch bands, drinking straws, spoons, cups, combs, greeting cards, stickers and business cards. In the cosmetic area a use has been found in nail polishes, light-enhancing make-up and temporary hair colorants. Photochromic can also be used as anti-counterfeit markers on garments and anti-tampering devices on packaging printed documents. For instance, a significant use is as security markers on documents, banknotes and passports, as exemplified by the US passport.

The products are also available from several companies in a variety of forms for these outlets including inks, microencapsulated and plastic resin concentrates.Photochromic materials change their colour by light and these materials are both organic and inorganic, but the most studied are organic photochromic materials. There are also photochoromic materials called heliochromic compounds, which are activated by unfiltered sunlight and deactivated under diffuse daylight conditions. Therefore they are suitable for sun lens applications. Photochromic materials change colour reversibly with changes in light intensity. Usually they are colourless in a dark place and when sunlight or UV-radiation is applied the molecular structure of the material changes and it exhibits colour. When the relevant light source is removed the colour disappears.[9]

2. THERMOCHROMISM

Thermochromism is an easily noticeable reversible colour change at specific temperatures. These materials are having special property with changing color whenever they are exposed to heat. [11] Typically, the thermochromic effect occurs over a range of temperatures, which is observed as a gradual colour change, i.e. continuous thermochromism.Two types of thermochromic systems that have been used successfully in textiles are: the liquid crystal type and the molecular rearrangement type. In both cases, the dyes are entrapped in microcapsules, applied to garment fabric like a pigment in a resin binder. Thermochromic materials using encapsulated dyes were developed in the 1970s. The following four materials are used in thermochromism:

1. Organic compounds
2. Inorganic compound
3. Polymers
4. Sol-gels

Organic Compound Thermochromism

Organic compound thermochromism has various applications for fibre, optical sciences, photo-storage instruments and optical sensors. The advantages of thermochromism of these organic compounds are that colour change takes place sharply and that there are many factors to control temperature easily.

Inorganic Thermochromism

Many metals and inorganic compounds are known to exhibit thermochromic behavior either as solids or in solution. Inorganic thermochromic systems have not enjoyed widespread textile applications as the observed change in colour often occurs in solution at high temperature. [9]

Some examples of inorganic thermochromic materials are the following:

- Cu2HgI4 is red at 20^0C but black at 70^0C
- ZnO is white at room temperature but yellow at higher temperatures
- In2O3 is yellow at a lower temperature but yellow-brown at a high temperature
- Cr2O3-Al2O3 is red at 20^0C but grey at 400^0C
- (Et2NH2)2CuCl4 is bright green at 20^0C but yellow at 43^0C;
- CoCl2 is pink at 25^0C but blue at 75^0C;
- VO2 at about 68^0C [7]

Applications of Thermochromic Materials

The majority of current commercial applications include temperature indicators for children's food containers (colour change plastic mugs and spoons); as indicator stripes on beer and colas to indicate correct chilling; on milk cartons to indicate that they have been refrigerated; and even on toilet seats to show time between uses. In the novelty area, logos on mugs, umbrellas, golf balls and in jewellery and cosmetics are common uses. For apparel applications, thermochromic materials have been incorporated into embroidery and weaving threads and coated onto transfer papers for thermal printing of a variety of textile fabrics and garments, such as T-shirts. Thermochromic materials are finding an increasing usage in architectural structures. Tiles with thermochromic properties have been designed for both internal and external application. One of the most important applications of chromic materials in architecture is in the environmental control of the temperature of a building using smart glazing in windows. The diverse ranges of non-textile applications to which thermochromic materials have been put include thermometers and temperature indicators for special purposes like security printing and non-destructive testing. They can indicate the proper temperature, e.g., cold enough for storage or hot enough for serving. [3]

3. IONOCHROMISM

It is the phenomenon of a colour change which is associated with the interaction of a compound or material with an ionic species. The organic structures that undergo the colour change on interaction with the ions are called ionochromes or ionophores. The colour change can be from colourless to coloured or coloured to colourless and is usually reversible. Ionochromism can be subdivided into chromism based on the types of ions that instigate the colour change. These chromic materials are sensitive to pH.

- Fluoroionophores, where ions cause a change in the fluorescent emission of the molecule.
- Halochromism refers to the colour change caused by a change in pH, due to either acids or bases;
- Acidochromism is reserved for the change instigated specifically by acids.
- Metallochromism applies where metal ions cause the change.

Ionochromic Compounds

The main commercially important pH sensitive dyes are phthalides, triarylmethanes and fluorans.

Applications of Ionochromic Materials

For instance their use as humidity indicators, thermal sensitive copying papers, in facsimile papers, and in digital and other forms of imaging, where irreversibility is one of the desired properties. However, there are still very significant uses of direct thermal printing in point of sales receipts, admission, transportation and lottery tickets, medical records, baggage tags, postage stamps, fax paper and delivery and food retailing labels. Nowadays it is an essential requirement that the printing of digital images be in full colour. [3]

4. HALOCHROMISM

Halochromism is the reversible colour change due to a change in pH of a solution. Halochromic compounds include phenolphthalein and titanium dioxide. The compounds themselves are weak acids or bases and become involved in acid-base reactions. A change in the pH causes a change in the ratio of ionized and non-ionized states, and, since these two states has different colors, the color of the solution changes. By far, the widely known chemical classes of pH-sensitive materials are the acids, bases indicators. Function of pH and the action is reversible. Usually these materials are prepared from various combinations of such monomers and polymers such as methacrylic acid, methylmethacrylate, carboxy methyl ethyl cellulose, cellulose acetate, cellulose phthalate, hydroxyl propyl methylcellulose phthalate, hydroxyl propyl methyl cellulose acetate, hydroxyl propyl methyl cellulose succinate, diethyl amino ethyl methacrylate, and butyl methacrylate. [9]

Applications of Halochromic Materials

Halochromic textile might be employed for various applications, such as protective clothing; for example to indicate the presence of acid vapors. A Halochromic wound dressing is also regarded as beneficial. Such a dressing can indicate the progress of wound healing by a simple colour observation, as the pH of the skin varies during healing. Monitoring the acidity of sweat, urine, nasal discharge, etc. using a Halochromic textile is therefore valuable. Further, in water filtration, the pH of the water has an impact on the performance of the filter and therefore it is of interest to follow the pH of the water.[8]

5. ELECTROCHROMISM

When an electro active species undergoes a change in colour upon electron transfer (oxidation/reduction) the process is known as electrochromism. This process normally involves the passage of an electric current and is reversible. In the late 1960s, it was suggested that because of their reversible change in colour, electrochromic materials could be used to make coloured displays. [3]

Electrochromic material changes colour in a persistent but reversible manner by an electrochemical reaction upon the application of voltage. Electrochromism is the reversible and visible change in transmittance and/or reflectance that is associated with an electrochemically induced oxidation-reduction reaction. This method is also highly effective, but it requires the migration of ions. [9]

Electro Chrome Types

The materials that change colour on passing a charge are called electrochromes, and these can be classified into three groups.

- Type-I the colouring species remain in solution at all times during electrochromic usage
- Type-II the reactants are in solution but the coloured product forms a solid on the surface of the electrode following electron transfer
- Type-III encompasses those where all the materials are solids at all times, e.g.in films. The first type is used in car, anti-dazzle, rear-view mirrors; the second type in larger mirrors for commercial vehicles, and the third type in smart windows.

Electrochromic Chemicals

A wide range of both inorganic and organic chemicals

Inorganic Oxides includes [Prussian Blue and Metal Hexacyanometallates, Metal Phthalocyanines, Viologens (4,40-bipyridylium salts), Polymeric Electrochromes]

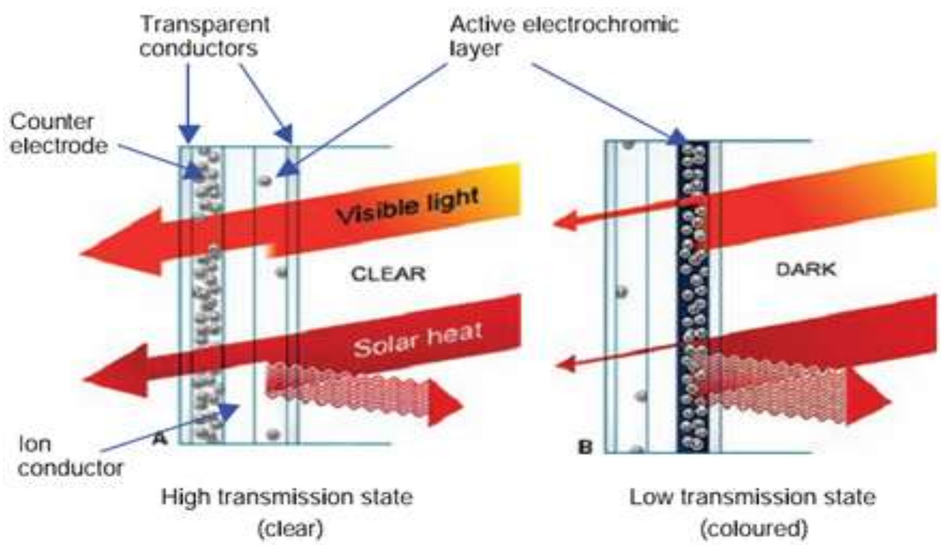
Organic Oxides include carbazoles, methoxy biphenyls, fluorenones, benzoquinones, napthoquinones and anthraquinones, tetra-cyanoquinodimethane, tetrathiafulvalene and pyrazolines.[3]

Electochromic dye:

Most available electochromic dyes are of inorganic oxides such as cobalt oxide, nickel oxide, molybdenum trioxide. The most important commercial application of the electrochemic dye in the textile is of US-Military IR camouflage material. [10]

Applications of Electrochromic Materials

The most successful ones are in electrically switchable rear-view car mirrors for anti-dazzle, and in glazing units for temperature and light control in buildings. However, there has recently been significant progress in the area of visual displays and data storage. They have a number of potential uses, including smart mirrors and windows, active optical filters.
Rear-view Mirrors are electrically switchable automatic-dimming rear-view mirrors for cars and trucks have been in commercial production in the US since the early 1990s. [3]



Schematic of a WO_3 electrochromic glazing unit.

Electrochromic materials are finding applications as specialized displays, electronic books, paper-like, and banner displays. Many chromic materials can be fabricated on plastic substrates, which is an advantage for future display applications.
The novel fabric contains interwoven electronic circuits from stainless steel yarns and thermochromic colour-changing ink, which are connected to drive electronics. Flexible wall hangings can then be programmed to change colour in response to heat from the conducting wires. Electrochromic inks have some applications in textiles, e.g., jacket, which could be black and every now and then it displays a pictures. [9]

Electrochromic materials, which change their optical properties in response to an electric field and can be returned to their original state by a field reversal, have major advantages:

- a small switching voltage (1–5 V)
- they require power only during switching i.e. low power consumption
- they exhibit adjustable memory, up to 12–48 hours [9]
- cheap
- switching is quiet fast
- easy transformation to make them in large amounts [14]

6. GASOCHROMISM

Gasochromism is closely related to electrochromism. The process involves an electrochrome, usually a metal oxide, such as tungsten oxide or WO3with oxidizing or reducing gases, most commonly hydrogen and oxygen, to produce reversible colour changes. The gasochromic properties of WO3films are much improved when coated with a thin catalytic layer of platinum or palladium. The catalyst dissociates hydrogen molecules into protons and electrons, which then diffuse into the WO3layer. This causes a change in the optical transmittance through small-polar on transitions just like the electrochromic process. The main applications of gasochromism are in smart windows for glazing and gas sensing of oxygen, hydrogen, nitric oxide, hydrogen sulphide and carbon monoxide. One of the potential advantages of gasochromic over electrochromic windows is their ease of construction into larger glazing units. [3]

7. SOLVATOCHROMISM

Solvatochromism can be defined as the phenomenon in which a compound changes colour, by a change in either its absorption or emission spectra, when dissolved in different solvents. It is one of the oldest of the chromisms, having been described as long ago as 1878, but nowadays it is usual to extend the concept of the ‘‘solvent’’ to include gels, micelles, polymers and films, as well as various surfaces.

Applications of Solvatochromic Materials

An obvious application of solvatochromism is the measurement of concentrations of small amounts of polar molecules in non-polar environments e.g. methanol in naphtha. In the food and drink industries solvatochromic analysis is employed in evaluating oil-based spreads such as margarine, in cooking oils and in wines and other alcoholic and non-alcoholic drinks. [3]Solvate chromism is normally used for swimsuits. Other materials have paint which can store light. Applications for this are e.g. working clothes in bad light circumstances or as guiding arrows during a power failure. [1] Solavtochromism is the phenomenon, where colour changes when it makes contact with a liquid, for example, water. Materials that respond to water by changing colour are also called hydrochromic and this kind of textile material can be used, e.g., for swimsuits. [9]

8. VAPOCHROMISM

Vapochromic systems are those where dyes change colour, often reversibly, in response to a vapor or an aroma of an organic compound or gas, and there is clearly a strong overlap with solvatochromism. Systems based on this principle can be considered as belonging to the optical branch of the family of ‘‘electronic nose’’ devices.

Applications of Vapochromic Materials

The main applications of vapochromic materials are in sensors for detecting volatile organic compounds (VOCs) in a variety of environments, including industrial, domestic and medical areas. [3] An example of such a device is an array consisting of a metalloporphyrin (Lewis acid), a pH indicator dye and a solvatochromic dye. Vaporchromic materials are sometimes Pt or Au complexes, which undergo distinct color changes when exposed to VOCs. [12] The dyes used to construct a 66 array were drawn from the following: (1) Lewis acid/base dyes (i.e. metal ion-containing dyes), (2) Brønsted acidic or basic dyes (i.e. pH indicators). Explosives are another important area where vapors of nitrotoluenes, H2O2and acetone need to be sensed quickly and on the spot.[3]

9. MECHNOCHROMISM

Chemicals can be put under stress in the solid state by mechanical grinding, crushing and milling; by friction and rubbing; or in the solid or solution state by high pressure or sonification. The change of colour under such mechanical actions is called mechanochromism. Pressure-induced colour change is known as piezochromism. This induced colour change reverts back to its original colour if the material is left in the dark over time or dissolved in an organic solvent. A chemical that displays this phenomenon is diphenylflavelene. When grinding or attrition is the stimulus the phenomenon is tribochromism. Light emission under these conditions is called triboluminescence. Tribochromism is the same as piezochromism, except that the compound does not revert back to its original colour in time if left in the dark or dissolved in an organic solvent. Barochromism is normally reserved for pressure induced spectroscopic shifts, especially in the study of naturally occurring minerals.

On a few occasions the term sonochromism has been used when the colour change occurs under high-energy sonification.

Applications of Mechanochromic Materials

Patents have been filed on the use of both piezochromic and tribochromic materials in inks and papers for security out-lets, in cosmetic applications, as stress and crack indicators in engineering and as pressure-sensitive paints for aerodynamic flow modeling. More recently mechanochromic properties have been observed in polydiacetylene nanotubes encapsulated colloidal crystals and ordered colloids. [3]

10. CHORNOCHROMISM

Chronochromism has been adopted to describe those processes where there is a change of colour with respect to a defined period of time. In all cases they are examples of indirect chromism, since the colour change occurs by one of the other chromic phenomena: ionochromism, photochromism, thermochromism, gasochromism or vapochromism.Systems have been devised using pH indicators, leuco dyes and photo-chromic materials, placed in environments designed to allow the colour change to take place over a period of time predetermined by the application and hence giving rise to the term chronochromic. One example is the use in toothpaste of a mixture of Methylene Blue and sodium ascorbate. On brushing the teeth the two chemicals interact and the dye is reduced to a colourless leuco product. Complete disappearance of the original blue colour indicates the correct time for the user to brush their teeth. Another potential outlet is the use of indicator dyes in semi-permanent inks for the temporary marking of documents e.g. routes on maps. One such ink uses the ammonium salt of phenolphthalein. Ammonia evaporates with time leaving the colourless phenolphthalein behind.Another important area where time evaluation is important is exposure to sunlight and several systems exist which are designed to change colour after a certain level of exposure to UVB. These involve stickers or wrist bands covered with a formulation containing an acid release agent, e.g. iodonium and sulfonum salts or chloral hydrate which is activated by UV and pH indicator dyes such as thymol blue and malachite green, which change colour as the pH rises over time.

11. RADIOCHROMISM

Radiochromism is used to describe a process in which a material changes colour directly by absorbing ionizing radiation, without the need for any kind of thermal, optical or chemical development or amplification. Such radiochromic materials, in the form of films, have been used for years as radio-graphic dosimeters and for imaging in the medical field. In the past many chemicals have been used in this application, including leuco dyes, triphenylmethane cyanides, spiropyrans, anils, organic acids, stilbenes and formazan dyes. [3]

12. MAGNETOCHROMISM

Magnetochromism is the term applied when a chemical compound changes colour (due to mechanical deformation) under the influence of a magnetic field. In particular the magneto optical effects exhibited by complex mixed metal compounds are called magnetochromic .These brightly coloured colloidal suspensions change colour when approached by a magnet, the actual colour depending on the strength of the magnetic field, the effect being reversible. [3] Shape changes are the largest in ferromagnetic materials. Magnetochromic materials are usually inorganic in chemical composition and are alloys of iron and nickel and doped with rare earths. The full effect of magnetochromism occurs in crystalline materials. [13]

CONCLUSION

An exciting new era is opening in the field of textile materials due to development of innovative yarns, fabrics, functional finishes and coloration systems. Chromic materials occupy a unique place as they are exciting materials, not yet fully explored on textiles and come with associated problems regarding application on textile substrates. Photochromic/thermochromic colorants occupy a niche position within the coloration industry, the majority of applications in the textile sector limited to fashion, leisure and sports garments. [2] The majority of applications for chromic materials in the textile sector today are in the fashion and design area, in leisure and sports garments. Most photochromic materials are based on organic materials or silver particles. The lifetime of these compositions is rather short for industrial applications. Most thermochromic materials are organic materials, having a short lifetime and a limited range of temperature. For various applications, especially for textile applications, there is a need to develop the wide range of temperature and lifetime properties of these chromic materials. Electrochromic materials in textiles have many promising applications. Chromic materials are one of the challenging material groups when thinking about future textiles. Colour changing textiles are interesting, not only in fashion, where colour changing phenomena will exploit for fun all the rainbow colors, but also in useful and significant applications in work wear and in technical and medical textiles.[9]

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