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X-chrome Materials for Textile Products Adapted to the Needs of Newborns

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Smart textiles in healthcare are able to react on their own by adapting to their environment. They allow integrating functions and expand the design options. The development of these textiles will lead to create more comfortable products. The textiles of the future will improve our daily lives and offer new perspectives for industry, health services and the environment. To reach those objectives, smart products incorporate more and more innovative functional materials and fibers such as X-chrome materials with color-changing properties under pressure, temperature, light, etc.
In this survey we will present the state of arts of the x-chromic materials, and mainly x-chromic textile materials. An overview of the main textile applications of chromic materials will be discussed through ongoing research towards technical and smart textile applications. Applications as reactive indicators adapted to the user need with focus on newborns needs will be detailed.

Keywords: Newborn needs; x-chromic materials; smart textile.

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1. INTRODUCTION

Today, healthcare design has become a major feature of culture and daily life. This intellectual and creative process aims at harmonizing the human environment. Its role is to deal with and provide solutions to problems related to human health and the quality of his life. It examines care environments that can not only prevent injury, but provide compassionate care. Again, through these innovative processes, we can ensure comfort, safety and well-being, which limit the daily problems of a particular user target [1].

Thanks to new technologies that are well managed and well exploited, textile design is still an increasingly supported and even ubiquitous sector in the current concerns of people, who have specific needs. It aims to question and observe intelligence to generate new products with functional fibers, reactive fabrics or intelligent printing or manufacturing processes.

At present, the number of diseases is increasing because of the unawareness of people vis-à-vis rare, progressive, disabling problems, putting the lives of patients at risk and can be in some cases deadly. We therefore focus our research on the diseases and ailments of newborns. These vulnerable babies have many needs such as: comfort, safety, well-being and that those around them must be informed of their conditions: temperature, allergy, fall, colic.

Also, signs in newborns are often non-specific, which means that each sign can indicate almost any disease or problem. Hence, the difficulty of diagnosing diseases and especially those that occurred during the first month is very difficult, which allows each baby to react to his environment in his own way, to express his emotions and desires.

Research in the medical field must be of very great benefit to the individual and to health. However, this sector must accompany innovations in different fields, especially textile design. This collaboration makes it possible to provide effective solutions to the different needs or necessities and more particularly those of newborns, especially since smart textiles are considered as a second skin. Increasingly, it is interactive with the user and his environment.

Thus, the researcher and the designer must meet the specific needs of newborns through textile products. These babies require smart textiles with interactive, innovative, X-chrome materials, which can be a compromise between functionality and aesthetics. That is to say a means to ensure safety, detect the temperature of newborns and meet their needs to the user (medical executives, parents) with the color change effect [2].

After presenting an overview of the x-chromic materials, and mainly x-chromic textile materials, we will focus on newborns needs to design.

2. REACTIVE TEXTILE IN MEDICAL APPILICATIONS

Innovation in the medical setting that deals with newborns is the development of new products, devices or technological instruments. Everything is changing in the textile world, which is an important vector for satisfying the basic needs of the user. Several smart products allow for example to detect the movements of babies, adapt to the morphology, protect from the temperature and change color according to our mood.

In addition, the designer must take care of the perceptual, technical, aesthetic and above all functional functions of the product. The designer must be interested in a discipline aimed at the creation of objects, environments, graphic works... that are at the same time functional, aesthetic and compliant to the requirements of industrial production. To combine the functionality of the product and its aesthetics so that the user always remains fashionable, which allows the designer to follow the current trend and find solutions to the needs of users. As in our case study is to find reactive indicators to protect the state of newborns.

Today, the fields of applications and research have made various spectacular progress such as in well-being, biology, sport, medicine, automotive, high-level textiles, engineering, etc.

We don't create to have fun but to meet the needs of a client. In this case, each user (medical staff or parent) has essential needs for these babies. For this, the task of the designer is to analyze and provide solutions to these needs, especially in textile design. In this part, we will present some reactive textile products of indicators of a state relating to the health of the user [3].

Below some examples of functional textile:

2.1 Smart Dressing, Fall Intensity Detector

The first example, Fig. 1, features a smart bandage, which changes color to detect disabled sports injuries. This new kind of textile was developed by British researchers (Dan Garrett, Lucy Jung and Elena Dieckmann) in the year 2014, who found this fall intensity detector.

Fig. 1. Smart wound, fall intensity detector [3]

The objective of this product is to detect, to inform the patient or the entourage of disabled sports (soccer-wheelchair, rugby-wheelchair, seated skiing, etc.) in the event of a fall with a change of color. Even a major injury such as a fracture can go invisible if the athlete has reduced sensitivity and this can expose him to risks.

In addition, the garment is made up of several pockets with sewn tulle inserts facing the main areas (femur, tibia, fibula, abdomen, etc.), which are at risk of injury. Into these pockets is slipped a pressure-sensitive recyclable material. In the event of a fall, the fabric changes color by displaying its color in red, the intensity of which varies according to the level of pressure undergone.

Subsequently, at the end of training or competition, the color of the product changes to blue. Red colors immediately inform which areas have been abused. This allows both to intervene more quickly if the risk of injury is great or not and to avoid unnecessary X-rays if the shock is minimal. This innovation allowed the team of these researchers to be among the finalists for the James Dyson Awards, this product has already reached the marketing stage in 2015 because there are orders, which have arrived from the United States [24-26].

To conclude, it is a multifunctional product that gives security, comfort (physical and psychological) and is characterized by high technology that makes it smart and creative. The latter is at a great performance with proactive technology, which is made of an elastic, anti-perspirant fabric with ergonomic, comfortable seams and allows great freedom of movement in disabled sports.

Finally, this textile product offers a feeling of protection and comfort, with its role being to positively influence the psychology of disabled people, in particular the injuries of paraplegics.

2.2 Smart Dressing for the Detection of Wound Infections

The following example, Fig. 2, shows an intelligent smart bandage, which changes color when it detects an infection. British researchers from the University of Bath in the United Kingdom have developed this product in particular for monitoring severe burn wounds and which alerts the patient when he detects the formation of a bacterial bio-film [21-23].

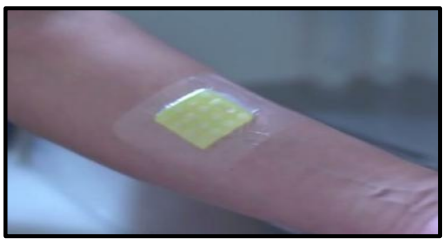

Fig. 2. Smart dressing for the detection of wound infections [4]

In addition, the objective is to reveal the presence of bacteria in a wound with a change in its color. The infection can lead to sepsis in case of severe burns or if it is not detected in time and sometimes even the death of patients. According to study results published in the ACS journal Applied Materials and Interfaces, standard testing of this dressing took up to three days to reveal only the presence of the bacteria. The dressing quickly changed its color to fluorescent green after 4 hours and also after a few minutes of detecting a bio-film. The purpose of this smart product is to:

- Shorten detection times indirectly.
- Reduce the use of preventive antibiotics and the number of cases of sepsis because after a burn, infections are the most frequent complication for severe burns. But, if they are not prevented, infections prevent healing and can lead to the death of patients.
- Detect the start of a wound infection by changing color.

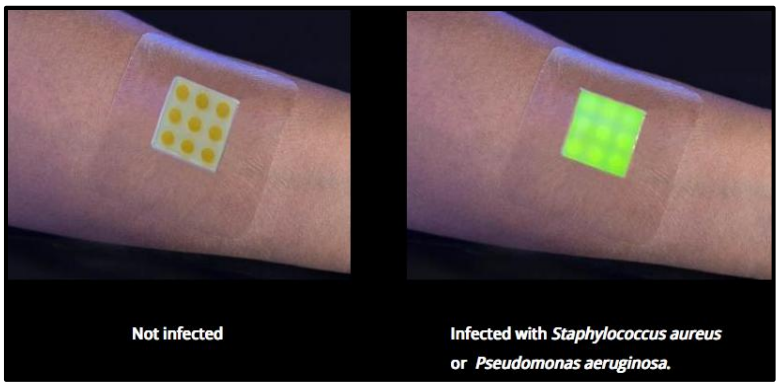

Fig. 3. Difference between material detecting or not bacteria

According to Dr. Toby Jenkins explains that: “all wounds contain certain bacteria that do not trigger an immune reaction, which does not cause infection. But when bacteria start to form biofilms and critically colonize the wound, it becomes dangerous for the health of the patient. Our technology makes it possible to measure this critical colonization point. That is to say that the bio-film is a normal way of life of bacteria, a community of micro-organisms (bacteria, fungi, etc.) which adhere to each other on a given surface, Fig. 3 [5].

Inside the dressing is a small capsule, impregnated with gel and releases a non-toxic dye. When he detects an increase in bacteria, it is lipid vesicles containing a fluorescent green dye and according to Jenkins announces that: “the vesicles are only about 100 nanometers in diameter and identify bacterial toxins. Beyond a certain threshold, the dye is released, which gives the dressing this fluorescent color. In an early stage, this functional product is a means of preventing, alerting patients and medical executives in a timely manner, when lesions begin to infect bacteria [27-29].

This bandage, Fig. 4, is a smart new technology and an important innovation in the health field to reduce the mortality rate of patients infected with wounds or burns. It will be a ubiquitous medical system in the future, which also reduces the unnecessary use of antibiotics.

To conclude, these two examples of smart textiles are summarized in the Table 1. They are high performance with proactive technology and provide satisfaction for people with specific illnesses or needs. They are also used as an indicator of disease and can be considered as an interactive second skin [7].

Thus, the scientific research laboratories present axes of reflection which analyze innovative situations in all fields and flourish in the interaction between design and the fields, which are close to it. It is no longer a question today that the garment hinders in any way whatsoever by the freedom of movement of our body but on the contrary, by its lightness, its protection and also promotes a real physiological comfort of the human being [8].

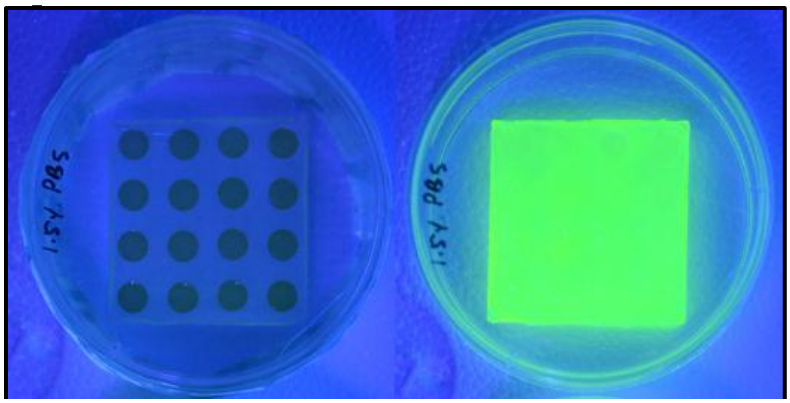

Fig. 4. Material of the bandage [6]

Table 1.Summary of the advantage of changing color product

Sample	Design date	Objectives and advantages
Intelligent product that changes color in the event of a fall.	2014	• Detect paraplegic injuries by a color change. • Propose solutions through innovative materials and materials. • Inform patients or the disabled sports entourage of (wheelchair football, wheelchair rugby, sit-skiing, etc.) in the event of a loss. • Characterized by smart technology that makes the product innovative and creative.
Smart dressing that changes color when it detects wound infection.	2017	• Alert the patient when he detects the formation of an infection. • Reduce unnecessary use of antibiotics. • Early presence of bacteria in a wound with a color change. • Reduce sepsis and patient mortality. • Discoverdetection times indirectly. • Improve the health, safety and comfort of people with wounds

More and more designers, researchers and engineers are working with laboratories or companies. They imagine things for us, which are essential in understanding the fundamental transformations of the design concept in relation to textiles like another skin, another life, other needs, other desires, etc.

We also conclude that technology carries technology-centered innovation and user-centered innovation. Indeed, technology-centric innovation manifests itself through the integration of new technologies. And concerning user-centered innovation, we can say that the examples of innovative textile products centered on the basic needs of people take into account their problems and their contexts in which they live daily. In this sense, the massive appearance of these new technologies is changing the world very quickly to solve the needs or problems identified in our daily lives [30].

3. X-CHROME MATERIALS

X-chrome materials are chromic materials, which change their colors under the influence of a variable X. The external stimuli "X" can be varied in the presence of an intelligent factor such as pressure, light, humidity, etc. They can return to their initial state when this factor is removed [9].

Then, this technology is classified among the family of intelligent textile material. It has different characteristics, which allow it to function as: “a sensor (detecting signals), an actuator (performing an action on its environment) or sometimes as a processor (processing, comparing, storing information). Therefore, it is capable of spontaneously changing its physical properties, in particular its color, in response to natural or provoked excitations from outside or inside the material [10].

According to Lucile Cornu, she announces that X-chrome materials: “whose color change in absorption (body color) is the response to a variation of stimulus, are pigments that can be used to probe the environment surrounding them [11].

These materials will see their color modified by a variation in pressure, by an electric field, by a variation in temperature or by exposure to radiation.

Moreover, the latter are divided into four main families such as: piezochromes, electrochromes, thermochromes and photochromes. For each of these materials, we will discover their main characteristics, their properties and their classifications. But, in the field of technical and intelligent textiles, photochromic, thermo-chromic and electro-chromic materials are the most widely used.

3.1 Photochromic Materials

Photochromic materials are part of the vast family of X-chromic materials. More specifically, they are chemical substances, which change their colors reversibly, under the action of light (electromagnetic wave), most often ultraviolet (UV). They fall into two major categories: organic materials and inorganic materials [12].

Concerning photochromic organic compounds, they are available, varied, degradable by UV, oxygen, free radicals and their reversible chemical processes are generated by light. Indeed, they have the advantage of a wide variety of possible tints, which are commercially attractive and which are used as classic colorants for painting, printing,... The properties of these materials are due to the passage between two forms of isomers caused by exposure to light radiation. The photochromic process is not limited to organic molecules alone, but it is also found for inorganic compounds. With regard to the most promising inorganic materials are caused by the change of the electronic configuration of the metal ion or the geometry, conformation of bonds around the metal site.

The photochromic property is related to four main factors, which are: the temperature at which the phenomenon takes place, the rate of conversion from the ground state to the photo-induced state, the lifetime of the photo-induced states and the loss of reversibility of the process. These factors then vary depending on the nature of the chemical process, depending on the nature of the components used, the coloring of which is then modified under the effect of light excitation following the appearance of a metastable state.

In fact, the color of these materials is strongly dependent on the interaction between the radiation to which it is exposed and the electrons which are distributed in the material, dictating the positioning of the absorption bands in the energy space. They are usually sold in raw form, microencapsulated, or in various masterbatches. In this context Cédric Cochrane, MarylineRochery and Carla Hertleer declare that: “it is preferable to use these photochromes by incorporating them in a polymer matrix, in microcapsules and/or with stabilizers and barrier polymers [13].

ViolaineCoué, RémiDessapt, Martine Bujoli-Doeuff and StéphaneJobic announce that the development of the photochromic material: “results from a modification of the electronic composition of the material under excitation which induces a modification of the absorption spectrum in the visible. » It can be reversible (change of color at a defined light intensity and it returns to its original color when the light intensity recovers its initial level) or irreversible (permanent color change above a defined light intensity) [13].

This type of material is successfully applied to make new devices in paintings, toys (dolls' hair), advertising objects (parasol), sunglasses, security badges, etc. Also, we find these photochromes on clothing, but UV radiation is harmful in high doses to human tissues. They are susceptible to malignancy since our senses are unable to measure cumulative doses.

In this context, some designers have created reactive smart fabrics, which change their colors according to the position of the observers. This phenomenon is possible thanks to photochromic materials, because this multilayer process allows the refraction of a light beam in each passage to a new layer, therefore, it is an observation of multiple shades of colors. The parameters processed by the textile are of different natures and can be emitted directly from the body itself because it is an emitter of a light signal. There are thus photochromic materials, composed of materials having different reflection indices. For example the SolarActive® brand is the manufacturer and

Fig. 5. Different applicatons of piezo-chromic material in fashion

supplier of 100 products, such as visors, angled manicure, sunglasses, printed t-shirt, embroidery yarns, flip flops,… Fig. 5, which change color in sunlight. This technology offers high-end color-changing screen printing inks for heat transfer printing. This custom heat transfer color changing technology and iron transfers instantly change colors in the sun [14].

3.2 ThermochromicMaterials

Thermochromic materials present a modification of the color of a material according to a variation of temperature. The first developments appeared in 1992, in the form of T-shirts or sportswear. This phenomenon is divided into two main families: these materials can be reversible (the material regains its original color after cooling) or irreversible (the color obtained after cooling is different from the initial color). Thermochromic behavior: "can be obtained from different mechanisms:

- The crystal field.
- Load transfer.
- Modification of the chemical structure.
- Physico-chemical phenomena changing with temperature. »

On the one hand, the first family is the most used, the majority of thermochromic materials that we encounter in everyday life are organic type materials. However, these materials have different properties, which are mostly irreversible and above all only work at low temperatures. They allow preservation of the color acquired during heating after cooling.

Among these organic thermochromes, the most common materials are liquid crystals and leuco-dyes, which are used in a temperature range from -30°C to 120°C and make it possible to detect changes of the order of 0 .1°C. The use of these latter materials can be as a luminescent rewritable paper for applications in the food industry or a temperature indicator. The costs of leuco-dyes are lower than that of liquid crystals having an ease of incorporation into plastics and inks [15].

The applications of this kind of materials do not require a desired precision in the measurement of the temperature variation to the nearest degree. Organometallic "spin transition" matrices are known for their thermochromic properties. In these materials, the color variations are due to the change from a low-spin to a high-spin configuration of a metallic element. Atoms of electronic configuration like iron(II) oxide usually appear in the laboratory as a black powder. In this geometry, they are split by the crystal field into two groups allowing, depending on the temperature, the transition from a low-spin ground state to a high-spin state or vice versa. During cooling, these materials exhibit a thermochromic behavior with a transition from a white color to a violet color [31].

However, organic materials have a drawback, which is their degradation when the temperature increases too much. This is the reason why many inorganic matrices have been the most studied and synthesized by scientists. Inorganic thermochromes are oxides, which are part of the family of transition metals such as: phase transitions accompanied by a change in electrical properties, vanadium oxide VO2 present under the effect of a temperature variation and etc.

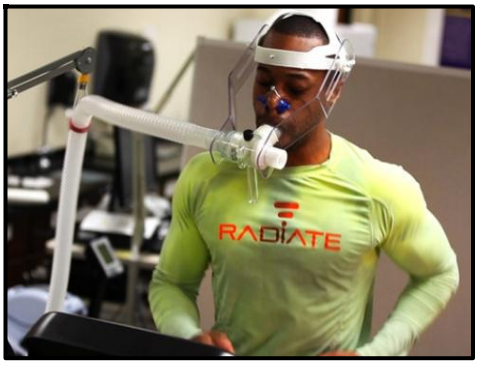

Fig. 6. Radiate t-shirt thermochromic textile during training [16]

According to researchers Cédric Cochrane, MarylineRochery and Carla Hertleer, they state that: "Inorganic compounds find very few applications in everyday life. If not in paint formulations, in pencil ink to indicate hot spots, often for temperature ranges from 120°C to 200°C. The fields of these materials are very varied in different applications: coatings, heat-sensitive leukodye ink pens, thermochromic fabrics based on liquid crystals, automotive paints. One such example is the thermochrome T-shirt, which was created by designer Boris for athletes, Fig. 6.

At room temperature, this smart garment that reacts to body heat. It shows a thermal vision of the parts used by changing color, the purpose of which is to see which muscles are working the most during exercises. Thus, as soon as the blood vessels widen or the muscles swell, this T-

shirt is a detection tool because it alerts us to the muscles that are working with a change of colors in the areas in action. It also has a thermal insulation system that will wick away moisture for great comfort during training [17].

In addition, the fabric in this product has been created by combining a thermochromic ink with the material, which has the effect of reacting instantly to the heat released by the muscles during a targeted activity, causing an immediate coloring on the fabric.

We can see that in some thermochromic materials, there is the presence of a substance with the ability to undergo a color change under the effect of a temperature gradient. Thus, different colors are possible and can be obtained at different temperature values with reversible or irreversible systems. A part can for example be blue when cold and can lose its color when hot. We can mix the dyes and have a purple product made up of blue and pink pigments, which will be able to change to pink at 30°C, then to white at 40°C [18].

3.3 Electrochromic Materials

Electrochromes, which we can also include in the family of X-chrome materials (photochrome and thermochrome, etc.), have the ability to change the optical properties (reversible color change in the visible) under the action of a current or electrical potential difference. This color change is caused by controlled oxidation-reduction reactions [32].

In addition, the term electrochromic derives from the English word 'electric' and from the Greek 'Khrôma' which means color. This phenomenon has been known since the beginning of the 19th century, chemists have extended the range of electrochromic materials and they now offer extensive color palettes. The operating principle of electrochromic materials, introduced in 1961, in a slightly different context by John Platt, of the University of Chicago, which is based on simple chemical reactions for the exchange of electrons.

Then, under the impetus of the work, the idea of electrochromic materials developed rapidly, which could be the basis of devices built on the principle of electrochemical generators. And according to Hakim Moulki, he states that: “Electrochromic devices are multilayer systems that undergo color changes like the optically active materials that constitute them. There are then four families of electrochromes. Two inorganic families that include transition metal oxides and Prussian blues.And two organic families that include conductive polymers and viologens.

As long as they are applied at a low electrical voltage, electrochromic materials change their color, fade or intensify. In these materials, the circulation of electric charges leads to an oxidation (loss of electrons) or reduction (gain of electrons) reaction. And as ROGER MORTIMER affirms that: “the optical properties of the reactive molecules are modified and the wavelengths of light which are absorbed are thus modified. If these wavelengths belong to the visible spectrum and the color of the material changes. These reactions are very easily achievable and controllable in solution, but the production of textiles, or flexible and fine structures, electrochromes, is less easy [19].

Many prototypes of electrochromic devices have been designed and ideas for applications of electrochromic metals already exist commercially. Among those, we find this phenomenon in: motorcycle helmets, multicolored display screens, goggles, mirrors in the automotive sector (automatically switch from the discolored state to the colored state in order to reduce the light reflected from the headlights of cars coming from behind), airplane windows (can be darkened at will to reduce light in the cabin.),... Moreover, in the field of textiles, we find these materials in the camouflage and smart fabrics that we can call chameleons. The figure below represents some applications of electrochromic materials.

Other works that focus on the design of electrochromic devices are flexible, compatible with textiles. These devices, which rely on the fact that conductive plastic films, are already commercially available. The films are most often made of polyethylene terephthalate coated with a layer (typically 0.1 µm) of indium tin oxide (ITO). ITO has the particularity, when it is synthesized under certain conditions, of being transparent in the visible and of being a good conductor in electricity. In addition, these films make it possible to create sealed devices that are less sensitive to degradation.

3.4 Piezochromic Materials

Piezochromic materials are materials that change color under the effect of a variation in pressure. Reversibility is obtained after storing

the material in the dark and/or dissolving it in a suitable organic solvent.

Next, we present the example of the "OliKrom". According to YannCochennec, he announces that this French company is developing: “intelligent pigments to create inks or paints that are sensitive to changes in their environment. Simply put, coatings change color when there is a disturbance of temperature, light, pressure, solvent, or gas. The company has developed a size that can identify with the naked eye any impact beyond a determined threshold. Thanks to the change in color of the paint, the effect of a variation in pressure following an impact or deformation will be visible.

OliKrom was created to respond to the problems of designing intelligent products, which are able to respond reversibly or irreversibly to the action of color change. It is based on two patented technologies. The first technology is the reversible piezochromes whose color changes after pressure is applied, then returns to the initial color when the stress returns to its original level. And the second technology is the irreversible piezo-chromes whose color changes permanently above a defined pressure, Figs. 7 et 8.

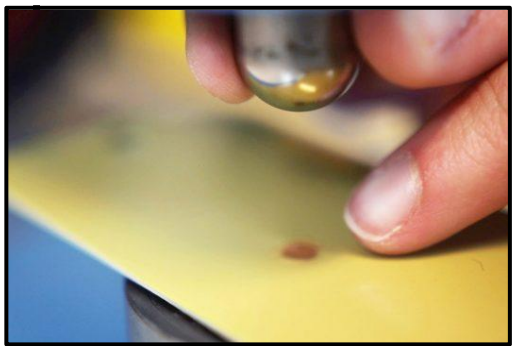

Fig. 7. Irreversible piezochromic material

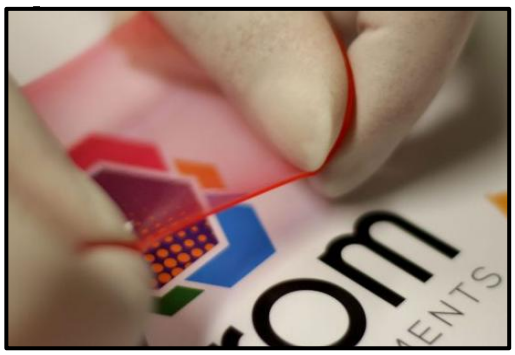

Fig. 8.Reversible piezochromic material [19]

In the field of smart pigments, the know-how of OliKrompiezochrome technology accompanies industrial developments for many sectors such as: in safety, we find food packaging (temperature indicator of the consumption of a product such as wine, bottle). And in advertising, we also find it in toys, cosmetics (labels, cups, perfumery bottles),...

The objective of this technology is to provide innovative solutions, which involve a new generation of hybrid pigments which combines the recognized solidity of metal ions and the flexibility of molecular matter. Currently, these piezochromes are receiving astonishing attention due to their potential applications as user-friendly pressure indicators, especially in the fields of safety, packaging, motorization, paint, shock detection varnish, etc. So, this type of material is a global solution to our research from design to production to save time and improve efficiency.

Finally, these smart materials are mainly composed of a polymer matrix, in which a liquid crystal and an optically active substance are distributed. The key point in their implementation is to be able to follow the damage during use. However, monitoring operations constitute a significant cost for the user, it becomes essential to develop these sensitive materials for the detection of impacts and to gain both in terms of cost and reliability.

3.5 Other X-chrome Materials

There are other types of materials whose color changes depending on an external stimulus. However, these materials currently have no application in the textile fields, which are:

- Halochrome: this is the change in color of a dye or a pigment under the action of an acid or a base. The color change is caused by the formation of a new chemically obtained chromophore.
- Tribochrome: a crystal radically changes color under the action of friction. Unlike piezo-chrome, tribo-chrome is not reversible.
- Solvatochrome: the color changes color under the action of a solvent (like the colored indicators changing according to a variation in pH) [20].

Finally, the characteristics of these X-chrome materials and their color change effects. Advances in new materials and device assembly

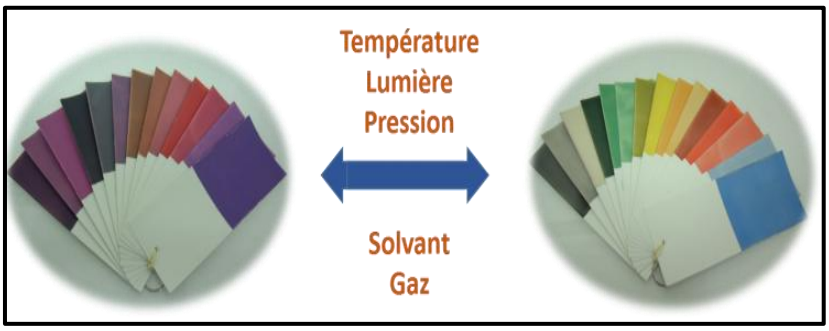

Fig. 9. Stimulus change color material

technologies that are beginning to emerge in the textile industry are growing. Among these, smart materials such as X-chrome materials, which change their colors under the effect of an environmental stimulus. They are divided into four main families: the piezochromes which change their colors by a variation of pressure, the electro-chromes by an electric field, the thermochromes by a variation in temperature and finally the photochromes by exposure to radiation (light).

X-chrome materials have the ability to change their physical properties when subjected to stimuli, which are ideal candidates for integrating sensors. These sensors can be very varied depending on the type of stimuli to which they are sensitive in their mode. A sensor then indicates the stimulus (pressure, temperature, light, humidity, etc.). In this sense, the monitoring of these variations of stimuli can be decisive for the proper functioning of equipment and also to mark the presence of an intelligent factor. This is why these materials are increasingly researched and developed by allowing the detection of variations in environmental factors, Fig. 9.

Many opportunities rely on X-chrome technologies such as: automobiles, inks, paints, coatings and also clothing. Every industry is showing growing interest in the added value that color changing functionality could provide. So X-chrome materials add a dynamic extension to use by its color.

Indeed, in textile design, we always look for an aspect of novelty as for the integration of intelligent capacities with a change of color in our clothes. A number of textile designers use color changing materials on fabrics. But, this innovation is not yet used in the field of health to bring comfort, safety with the attempt to launch into markets with greater added value to design an innovative garment, both functional and aesthetic.

The relationship between textile design and technological innovation has made it possible to present new materials and smart textiles specifically in the field of health. But, when these new technologies are well managed and well exploited, we can obtain more comfort, well-being and also limit the daily problems of a particular target user, in particular the needs of newborns.

After some examples review, the following part is dealing with conceptual parts, to design textile product for newborns, with the integration of X-chrome materials whether for more functionality or for more innovation aesthetic. That is to say, these intelligent materials make it possible to have a comfortable garment capable of detecting the risks of the newborn. Next, we will focus on the importance of the choice of X-chrome materials and their characteristics to ensure the comfort and safety of newborns,... and to inform about their state of health and well-being. Beyond their main functions, these materials are a source of inspiration for designers and creators depending on how they are used.

4. CASE STUDY: DESIGN OF SMART CLOTHING FOR NEWBORNS, PERFORMANCE FOCUSS

A number of researchers and designers have started using X-chrome materials in the field of textile design for now, but not really in the field of health. Indeed, the objective of our study is to reflect on the contribution of the choice of materials in the design of an intelligent garment for newborns by emphasizing X-chrome materials and their effects.

For this reasons, our case study is to design smart textile product integrating X-chrome

material, whether in functionality or in aesthetic innovation and their characteristics to satisfy the necessities of newborns.

4.1 Integration of X-Chromes Material Innovations

Smart textiles are able to react on their own by adapting to their environment. For this, they incorporate X-chrome materials with color changing properties under pressure, temperature, light, etc. In addition, these materials present a catalyst for research, development in aesthetic innovation and fabric functionality for newborn clothing.

4.1.1 Functionality

Thanks to technological innovation, newborn clothes can provide several functional properties such as (lightness, resistance, absorption, adhesion, etc.) to textile fabrics. But, researchers are now going further by directly endowing natural fibers with new properties such as: moisturizing, healing, securing, etc.

Functionality and objective performance have the ability to sense intelligent information in its environment and respond to it with specific behavior. They have conquered their place and are increasing their presence in almost the entire textile sector. These are increasingly being developed by researchers, especially in the health sector, with the aim of facilitating and relaxing babies.

Tissues are no longer confined to protective functions. They are breathable, thermoregulating, anti-UV or anti-bacterial. These are functional fabrics, which meet new needs. » In our case, we are looking for textiles that are more comfortable, secure, practical, better suited to all the conditions of use of newborns and which meet their needs because the user (parents / medical executives) does not understand the needs of these babies. But, these textiles must also be easy to maintain in the wash because newborns get dirty a lot and for that, they need clean and easy to wash clothes. Functional fabrics (antimicrobial, anti-stress, thermoregulatory, antiperspirant, etc.) must also facilitate babies' needs and meet functionality criteria.

4.1.2 Aesthetic innovation

The textile design must be interested in the aesthetics of the garment so that the user always remains fashionable and follows the trend. Newborn clothes must take into account the criteria to improve aesthetic innovation. Among these criteria we find:

- Durability: Babies seem to need several clothes because they will be larger than average from birth. The durability represented in the textile material which is more resistant and its color does not change, does not degrade, but, it must be durable all the time during use.
- Visual sensation: the newborn shows remarkable capacities for assimilation, response to the surrounding world and his five senses are already in action to capture everything around him. He mostly perceives visual sensations such as bright colors that capture their attention the most. So, movement and color change are baby's sensory abilities with the goal of knowing two functions. The first is functionality, i.e. the baby must know the colors in these clothes and the second is aesthetics.

4.2 The Contribution of X-chrome Materials in Our Case Study

A newborn whose needs are not clear will try to satisfy them by another means, often by a different behavior (crying, anger, shouting, etc.). Conversely, a newborn whose needs are met, feels good inside, adopts more adapted behaviors and cooperates much more easily.

Moreover, X-chrome materials become a kind of second skin and a means of research to detect, protect and inform the states of babies. Thus, it is possible to apply electrochromic materials to textiles, it is a technique applicable to all fabrics offering a wide range of colors. And meanwhile possible applications are camouflage clothing for the military, heartbeat detecting clothing for the elderly,... These sought-after functions fall into several main categories such as: comfort, safety, etc.

4.2.1 Features to ensure comfort

Innovation in textile design presents the industry with a catalyst for technological development, which allows researchers to create new areas of research and interest aimed at newborns to improve their comfort and their adaptation to the body in all physical and thermal conditions such as (cold, temperature, protection against climatic changes, ultraviolet rays, etc.)

For the first month, the baby spends most of his time sleeping. But, it is important to choose a comfortable light garment to offer him an incomparable feeling of comfort with natural fibers, which have specific characteristics. These clothes must be so soft because of their sensitive skin, by avoiding synthetic materials.

Newborns need to wear flexible and comfortable clothes that do not hinder their freedom of movement. During the first days after birth, her protective or heat-producing mechanisms are not yet mature. This is explained by the thin skin of the newborn, which promotes a much higher level of thermal skin conductance than in adults. To do this, researchers and creators are always looking for breathable natural materials that provide more physical and thermal comfort for newborns.

4.3 Features to Inform Safety

Nowadays, there are many materials, shapes or types of protective clothing, their roles are obviously to ensure individual safety for uses. These protective garments vary a lot from garment to garment and depend on the material of which it is made, its design, its condition and the way it is worn. The latter represent only very limited volumes but considerable added value to reduce risks and specific functions.

In this sense, the role of smart functional clothing is for more safety and daily protection of newborns. We are therefore fully responsible for its safety, through attention and precautions. The solutions to ensure good safety in babies and avoid the most common risks is to install a safety barrier. This barrier is created thanks to certain precautions, such as:

- Protect from external environmental conditions.
- Avoid clothing with drawstrings at the neck or waist, for example (hooded sweater with a string).
- Pay attention to everyday risks (fall, burn, shock, etc.).
- Avoid clothes containing chemicals and decorative elements such as beads, because they come off and can suffocate them.

Thanks to technological innovation, functional clothing requires a high performance level of safety in newborns. This level is represented in protection against drops, heat, chemicals, UV (skin cancers) and allergies. For this, researchers, among other things, designers must use the means, methods and techniques to reduce the dangers surrounding babies. That is to say, they must design innovative and functional clothing to protect health, safety and detect risks and inform about the condition of the newborn.

4.3.1 Features to improve the needs of newborns

In smart textiles, functional clothing is increasingly able to meet different requirements and needs, especially those of the newborn. In this context, the newborns needs are vital necessity, essential to the individual to maintain life and ensure his well-being. Thus, the newborn is entirely dependent on his environment to ensure his physiological and emotional stability. It is therefore essential that we are able to understand its different needs in time.

In addition, newborns are not yet able to inform parents of its need and intensity. But, parents try to guess the necessary condition and needs of their new babies. These physiological needs are necessities such as (to breathe, to eat, to eliminate, discomfort, to move, to maintain one's temperature,...).

However, the researchers resorted to the materials themselves bringing their own functions to the clothes, which are multifunctional and able to adapt to the necessities. These clothes become a way to increase our sensitivity, stay alive, ensure well-being and exchange information with our environment. This means has the purpose of improving, protecting and identifying the needs or important requirements of the newborn.

The objective of our study is to reflect on the importance of the choice of materials in the design of clothing for born levels with an emphasis on X-chrome materials. Indeed, thanks to the cross between textile design and the medical field, we imagine a functional smart textile product for newborns. But through this research study, we thought of a functional specification, which aims to define the basic specifications that babies' textile products must meet through creative methods.

5. CONCLUSION

The fusion between the development of new textile design technologies and materials

science, guided us to carry out a study focusing on the needs of newborns. At the end of this work, the objective is to emphasize the choice of X-chrome materials and their effects on a basic garment, which becomes multifunctional and containing intelligent changes intended for newborns.

In this stage, we can say that this technological innovation (X-chrome materials) is a futuristic vision, a source of inspiration for engineers, designers, researchers and functional materials as an innovative path in all design research. We conclude that the most promising innovations and the most spectacular advances benefit the medical field to create intelligent products for prevention, monitoring patient care or indicating the necessary needs. The creation of smart clothing including X-chrome materials will have a research axis, which has brought us the scientific approach in the field of health and also a real impact on the textile industry in the coming years.

Nevertheless, this work can be considered as a starting point for the development of research and interests. The goal is to study not only how X-chrome materials work, but how they can play their roles in the daily life of newborns, whether in terms of functionality or aesthetic innovation. These materials gave us the opportunity to enrich our field of inventiveness through color changes. Then, we prove to represent this material as a reactive material and an indicator of the state of the newborns.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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