Development of Interactive Yarns for Textile Crafts

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ABSTRACT
This paper presents part of the preliminary developments of the ongoing textile design research project titled The Creation of Interactive Textile Crafts with Adoption of Environmental Sensitivity. The background of the project is firstly introduced and elaborated. With reference to the literatures and projects achieved by other forerunning researchers and designers, further attempts have been put on experimental trials of interactive yarn development for several textile crafts. From an academic perspective, the paper presents the feasibility of injecting interactive dimensions into traditional textile craftsmanships, and the possibility of intersecting traditional textile techniques with environmental sensitivities.

Keywords: Interactive Yarn, Textile Crafts, Interactive Textiles Materials, Environmental Sensitivity, Thermochromic Textiles, Photochromic Textiles

1. Introduction

Textiles have been evolving throughout the human history stressing different functions, for instances, spacial decoration, identity representation, heat insulation, physical protection, etc. By virtue of textile designers and researchers' efforts, more possibilities and functionalities are given to different soft surfaces. Quinn (2013), in addition to his previous publication in 2010, has reviewed a number of advanced textile pioneers and described that the practitioners in different fields are putting their heads together to change the design measures and purposes of contemporary textiles. It is an observable phenomenon that in addition to traditional functional values, more intangible and humanity values are being attached importance to both designs and design process. Antonelli (2011) also described the design practice is evolving from function focusing to that of the meaning. Transferring meanings, in other words, communicating through designs is one of the a key focuses in contemporary design.

Desiring for communication and interaction with external entities is an undeniable human nature and behaviour. Different degrees of communication and interaction measures involving sensory stimulation, emotion expression, message transition, meaning negotiation, etc, have been developed throughout history, and will continuously be explored. Communicating through textiles is no exception. Quinn (2010) pointed out that throughout the history, fabric surfaces have been made to communicate and capable to transfer information. Contemporary textiles will, without surprise, continue to perform as a message carrier. Thanks to the rapid textile technology development and digital revolution, textile design has entered a groundbreaking era. The possibility of imbuing textile design with the idea of interactivity increases in a significant way.

1.1 Interactive Textiles

New generation designers and researchers are pushing the boundary of interactive textiles, usually by injecting ideas and technologies of other disciplines through collaborations with other experts such as physicists, chemists, biologists, computer engineers, material specialists, etc. There have been an increasing number of interactive textile projects undertaken in the pass few decades. The textile pieces are able to change surface colour, visual, haptic property, shape and form when they encounter specific stimuli. Some smart textiles are even capable to emit sound, light, ratio frequency and electronic signal with support of advanced textile technologies. With reference to the previous projects, there are generally three directions of developing interactive textiles that researchers are exerting could be summarised. Firstly, applying electronics and soft circuits is one of the mostly investigated contemporary textile areas. Supported by external power source, sensor, micro-computer, conductive circuit and mechanism, the works are able to perform instantly perceivable effects to achieve the interactive behaviours. The micro-computerised systems further make it possible to integrate information technologies into textile pieces seamlessly. The second direction undertaken is to intersect responsive materials with textiles. With assistance of the responsive materials, usually in forms of dye and pigment, the textiles are capable to present different visual effects or even change its physical form upon external stimuli without electronic appliances. Thirdly, applying adaptive technologies is another direction to be considered. For example, by manipulating a meta-material that is capable to absorb, control and guide light waves to flow smoothly past the material surface, the piece could be 'dyed' by surrounding lights (Quinn, 2010). Among the three approaches, utilising responsive materials is the focus of this paper.

Applying responsive materials on textiles is one of the key foci being cultivated in creating interactive textiles. Several responsive properties have been explored including, thermochromic, photochromic, hydrochromic, shape-shifting, photovoltaic and electro-active qualities. Pioneers such as Aurélie Mossé of Textile Futures Research Centre, Erin Hayne and Nuno Goncalves of NunoErin, Hunag Wen-Ying of the Graduate Institute of Applied Art, Kathy Schicker, Kerri Wallace of Loughborough University, Maggie Orth, SquidLondon, etc have created a number of visually exciting environmental responsive designs. Surface colour and visual graphic changing are the most investigated approaches. There are several stimulating sources explored to achieve colour changing surfaces including temperature, wavelength and humidity.

Thermochromism is one of the common colour changing technologies in design industry. In order to achieve the temperature controlled colour changing properties, the colouring medium are usually filled with polymeric microcapsules. The capsule is made up of colorant and organic acid, which are surrounded by a solvent. When the temperature is below the solvent melting point, electron interaction resulting from the contact of colour forming components enable the colour to be visible. When the temperature reaches the solvent melting point, the contact between the components will be dismissed and stopped the electron interaction, therefore no colour will be seen. Figure 1.1 shows the general principle of a simple solid-transparent thermochromism. More complex colour changing behaviour could be achieved by combining various microcapsules with different solvent contents which response to different levels of temperature. Figure 1.2 shows a brief concept of multiple colour changing properties of thermochromic materials.

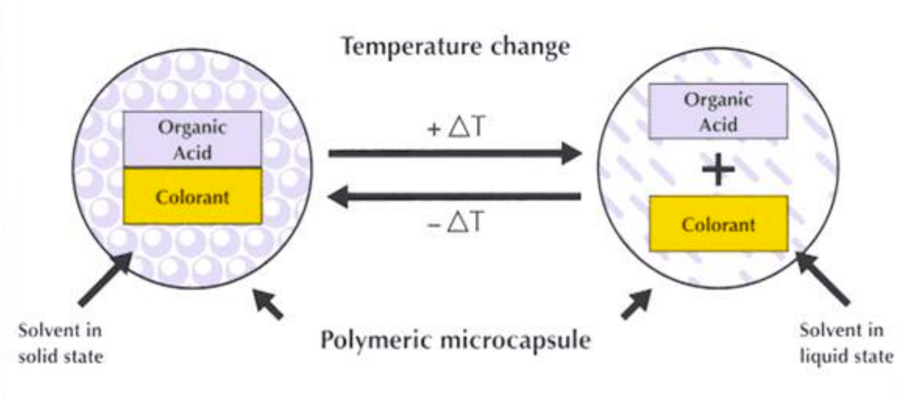


Figure 1.1 Principle of a simple solid-transparent thermochromism

Figure 1.2 Concept of multi-phrase thermochromism

There are different thermochromic mediums manipulated for different uses. Further to polymeric micro-capsule, slurry and masterbatch are also applicable supported by corresponding technologies. Figure 1.3 is a chart suggested by a manufacturer showing the applicability of the different mediums. By introducing the property early in the fibre stage, innovative possibility could be largely expanded by later processes, such as blending qualities and other finishing techniques.

Available Products / Applicability	Slurry	Microencapsulated powder	Masterbatch
Ink/Paint (Solvent)	×	○	×
Ink/Paint(Aqueous)	○	△	×
Plastic Injection/Extrusion	×	△	○

○Applicable、△Conditional、×Not Applicable

Figure 1.3 Applicability of different thermochromic mediums

The responsive materials, usually in forms of slurry and micro encapsulated powder, are commonly applied by printing and coating to the textile surfaces. With significant technical support, some designers are able to merge the responsive properties into textile substrates such as extruded plastic fibre, foam and rubber. The Swamp Stools (Figure 1.4) and Touch Wall Panels designed by NunoErin and the Motion Response Sportswear (Figure 1.5) developed by Wallace perform reversible colour changes when encounter ambient thermo stimuli. Orth further intersects the thermochromic material with computerised conductive circuits to create the multi-phrase colour changing textile projects including the Barcode Man, the 100 Electronic Art Years (Figure 1.6) and the Blip.

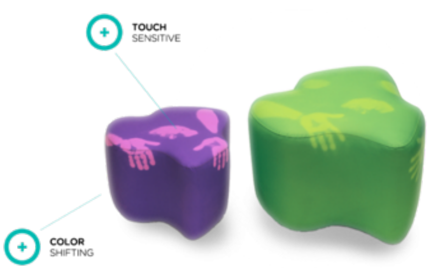


Figure 1.4 Swamp Stools by NunoErin

Figure 1.5 Motion Response Sportswear by Wallace

Figure 1.6 100 Electronic Art Years by Orth

Light is another explored stimulus for colour changing textiles. Photochromism is one of the newly investigated fields in textile design in twenty-first century. The photochromic behaviour is mainly related to the ultraviolet light reacting property of the molecule. Transparent to colour and colour to colour transforming are both possible. This technology has been used in various product designs and becoming popular, for example, the colour adjusting lens (Figure 1.7) invented by Transitions® Optical, Inc. is one of the most well-known photochromism applications. There are different mediums developed for various applications, including dye, slurry and micro-capsule, etc. Figure 1.8 shows a brief photochromic medium applicability suggested by manufacturer.

Figure 1.7 Colour adjusting lens by Transitions® Optical, Inc.

Available Products / Applicability	Dye	Slurry	Microencapsulated powder	PS Powder	Masterbatch
Ink/Paint (Solvent)	△	×	○	○	×
Ink/Paint(Aqueous)	×	○	△	○	×
Plastic Injection/Extrusion	△	×	○	×	○

○Applicable、△Conditional、×Not Applicable

Figure 1.8 Applicability of different photochromic mediums

Similar to photochromic materials, photo-luminescent material reacts to the contact with ultraviolet light. The medium glows in the dark after exposing under ultraviolet light environment. Schicker created an ultraviolet responsive installation, the Glow Bird (Figure 1.9) and a Woven Light series (Figure 1.10) by integrating photo-luminescent materials into printing and digital jacquard. Huang also practiced similar directions. The Lotus (Figure 1.11) and the Episode 1 (Figure 1.12) display different appearances under different light sources. Which means under different environments, diverse signifiers would be presented and therefore, different messages would be conveyed.


Figure 1.9 Glow Bird by Schicker

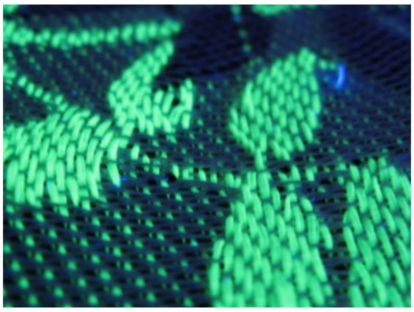


Figure 1.10 Woven Light by Schicker

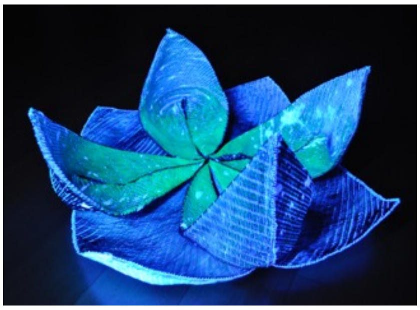


Figure 1.11 Lotus by Huang


Figure 1.12 Episode 1 by Huang

Hydrochromic textiles is the third area explored by contemporary textile designers. Hydrochromic binder turns into transparent from white when contacted with moistures. It sounds that colour is limited with only white and transparent are available. Yet thanks to the soft and flexible properties of the coating, the binder could be applied to diverse coloured surfaces without significantly affecting the textile's handle. By then transferring from white to any colours is logically possible. Normally, hydrochromic binder is used for printing. Products from SquidLondon are good examples, the colour changing Squidarella (Figure 1.13) and the raincoat series Romeo by Jaeger, Parkes, Roche & Collu (Figure 1.14) are printed with hydrochromic binder and will reveal colours underneath when it rains.

Figure 1.13 Squidarella by SquidLondon


Figure 1.14 Romeo by Jaeger, Parkes, Roche & Collu

Besides the colour changing properties, shape-shifting is another responsive quality applicable to complete interactive behaviours. There are generally three kinds of shape-shifting mechanisms, the thermo-responsive, photo-responsive and chemical-responsive. Since the activators of the first two mechanisms are comparatively easier to be reached in daily environments, the possibility of environmental application have been explored by textile practitioners. Thermo-responsive shape memory material is one of the smart materials being studied in recent decade. When an actuating temperature is reached, the shape memory materials such as Nickel Titanium Alloy, will return to a given shape from a deformed condition. Photo-responsive shape memory polymer is another shape-shifting material which reacts to ambient light condition. The polymer membrane converts light into electricity to generate the energy needed to change its physical shape according to the level of sunshine it encounters (Quinn, 2013). Aurélie Mossé have been conducting research projects in solar-responsive membrane. Her Reef (Figure 1.15) and the Constellation Wallpaper (Figure 1.16) move according to the light condition encountered and transform to different shapes.

Figure 1.15 Reef by Mossé

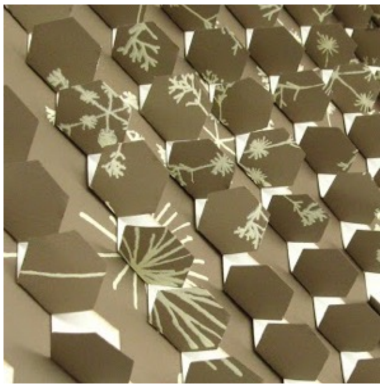


Figure 1.16 Constellation Wallpaper by Mossé

With reference to the reviewed projects, the application of environmental stimuli responsive materials on textiles design has been proved feasible and possesses numerous possibilities. However, most of the applications were achieved by advanced textile technologies such as digital jacquard, digital printing and sophisticated soft circuits engineering, the researchers believe that there is a niche to inject the high-tech responsive materials to traditional textile craftsmanships. As described by Campbell, Rey, Ehmann and Klanten (2014), techniques of a craftsman are like never-ending stories. One of the most valuable and respectable philosophies of craftsmanships is the lifetime chasing of the next possible level of perfection. Philipp Mainzer concluded a common wish agreed and shared by most of the crafters and designers that practitioners hope to contribute to the preservation and future development of traditional craft professions which helps to bring the valuable knowledge-experience hybrids up to date (Campbell, Rey, Ehmann and Klanten, 2014). Pushing boundaries and improving what have been perfected help to add values to diverse dimensions of humanity. The research team believes, in addition to the institutional values which textile crafts embrace, a new functionality introduced by the modern concept of design interactivity will merge with the traditional knowledge to bring textile crafts to a new age. Imbuing a new dimension of interactive ability, textile craftsmanship will be sustained and enhanced to an advanced level.

2. Development of Interactive Yarns

Material is the fundamental and primary level to start with. A significant portion of the previous projects were injecting environmental sensitivities to the textile pieces on fabric level by post-fabric-formation processes such as fabric dyeing, painting and printing. Some potential possibilities ,which could only be achieved by fibre or yarn level treatments, may be omitted. For examples, top dye melange effect and marled yarn knitting effect are impossible to be achieved in post-fabric-formation processes. Therefore, this study targets to initially start on pre-fabric-formation stages to enlarge the textile technique possibility. Logically, intersecting environmental sensitivities with textile materials on fibrous level would generate the greatest possibilities and highest level of manipulation for process afterwards. Nevertheless, in the early experimental stage, it is impractical to start with fibre development concerning the production scale and flexibility. Thus, as a primary step to explore possibilities, the study starts on the conditional optimised beginning level, yarn development.

The aim for this preliminary yarn development is to try and test the possibilities of sourced materials and eligible techniques. Attempts have been made to bring three environmental sensitivities to textile yarns, including thermochromic, thermo-reactive shape shifting and photochromic property. Three different methods of applying reactive materials on yarn have been explored, which are coating, dyeing and infusion. Initially, four environmental sensitive yarns were developed. Results of preliminary interactive yarn development are shown as the below pictures. Figure 2.7 shows the summarised general details of the yarns developed.

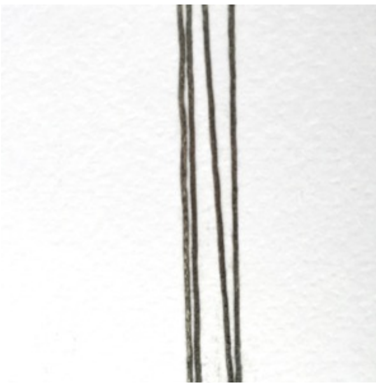


Figure 2.1


Figure 2.2

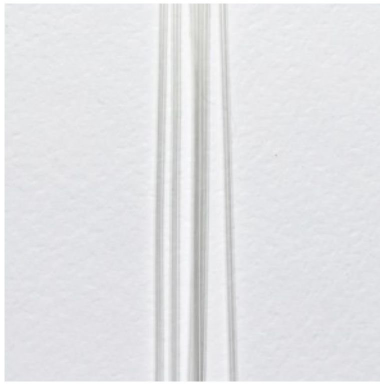


Figure 2.3

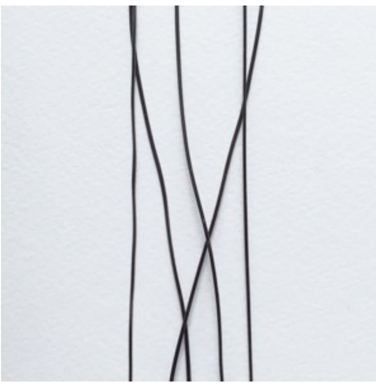


Figure 2.4

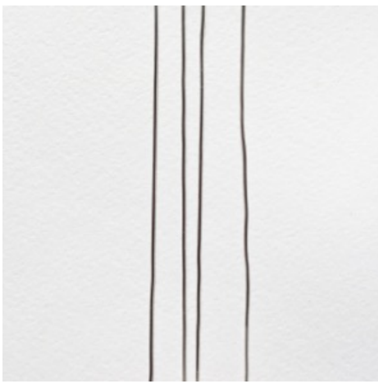


Figure 2.5


Figure 2.6

Figure 2.1 Yarn A - Thermochromic pigment coated cotton yarn
Figure 2.2 Yarn B - Thermochromic pigment dyed cotton yarn
Figure 2.3 Thermo-reactive shape memory tube
Figure 2.4 Thermochromic pigment infused thermo-reactive shape memory tube
Figure 2.5 Yarn C - Elongated thermochromic pigment infused thermo-reactive shape memory tube
Figure 2.6 Yarn D - Photo-luminescent pigment coated cotton yarn

	Yarn Substrate	Reactive Material	Colour	Medium	Treatment
Yarn A	Cotton yarn	Thermochromic microencapsulated powder	Dark Grey - Transparent at 31°C	Screen print transparent base	Yarn coating
Yarn B	Cotton yarn	Thermochromic microencapsulated powder	Pink - Transparent at 30°C	Screen print transparent base	Pigment dyeing, rinsing
Yarn C	Thermo-reactive shape memory tube	Thermochromic microencapsulated powder	Black - Transparent at 30°C	Screen print transparent base	Infusion by syringe, manual elongation
Yarn D	Cotton yarn	Photo-luminescent microencapsulated powder	Yellow - Aqua in contact of UV	Screen print transparent base	Yarn coating

Figure 2.7 General details of yarns developed

3. Trial Applications of Interactive Yarns

In order to test out the practicability of the developed yarns, seven experimental swatches were created to bring the developed yarns to real practices.

Thermochromic Swatch A was woven in 2/2 basket weave with developed Yarn A applied as wefts. A dark grey swatch with regular light grey dots was formed. As shown in Figure 2.9 and 2.10, when the swatch is stimulated by external heat, for example direct skin contact, the wefts of the contacted area change from dark grey to its original light grey. Figure 2.11 shows the recovering process while cooling down and the swatch recovers to the original state as Figure 2.8 eventually.


Figure 2.8


Figure 2.9

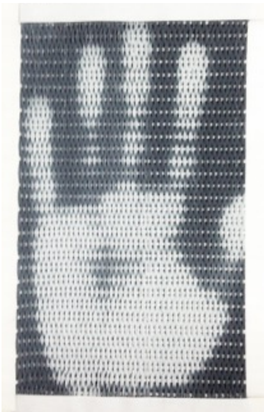


Figure 2.10


Figure 2.11

Figure 2.8 Thermochromic Swatch A under room temperature
Figure 2.9 Thermochromic Swatch A being heated by direct hand contact
Figure 2.10 Thermochromic Swatch A after colour changing
Figure 2.11 Thermochromic Swatch A recovering

Swatch B was a mix yarn crocheted piece utilising the thermochromic Yarn B. The colour placement engineered craft presents a delicate surface and structure which is not possible to be achieved by advance textile machinery. The swatch changes to white when being stimulated by external temperature increase and presents different visual effects throughout the changing process.


Figure 2.12


Figure 2.13


Figure 2.14


Figure 2.15

Figure 2.12 Thermochromic Swatch B under room temperature
Figure 2.13 Thermochromic Swatch B being heated by direct hand contact
Figure 2.14 Thermochromic Swatch B after partial colour changing
Figure 2.15 Thermochromic Swatch B after complete colour changing

Swatch C is a thermo-reactive piece created by crocheting with Yarn C. Originally, the stitches were in loose construction because the thermochromic pigment infused thermo-reactive shape memory tube was elongated and thinned by manual manipulation. By applying the actuating temperature to the elongated yarn, it shrunk and returned back to its original length and thickness. The swatch size reduced significantly and the stitches were tightened up and packed together. The stitch tightness after shrinking is hardly possible to be achieved by normal crocheting even very tight tension is applied. As shown in Figure 2.16 - 2.19, the swatch, in both pre-shrink and shrunken conditions, is capable to demonstrate a reversible colour changing property under external heat stimulation.

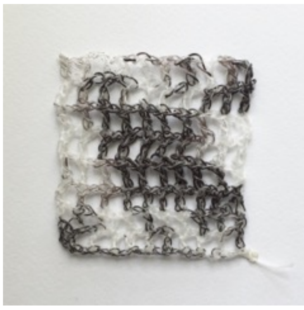


Figure 2.16


Figure 2.17


Figure 2.18


Figure 2.19

Figure 2.16 Thermochromic Swatch C under room temperature
Figure 2.17 Thermochromic Swatch C after colour changing
Figure 2.18 Shrunken thermochromic Swatch C under room temperature
Figure 2.19 Shrunken thermochromic Swatch C after colour changing

Swatch D is created by knitting the developed Yarn C. Similar performance to Swatch C is observed. Originally, the swatch had a count of seven wales within an inch. After it is shrunk by heating up, there are approximately eleven wales within an inch. This presents a possibility of gauge changing knitted fabric by utilising thermo-reactive shape memory material. Figure 2.20 and 2.21 show the colour changing ability of Swatch D

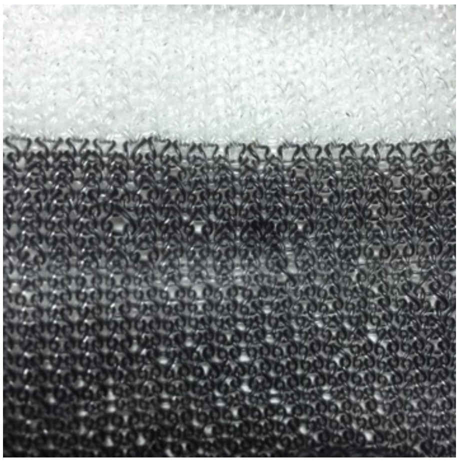


Figure 2.20

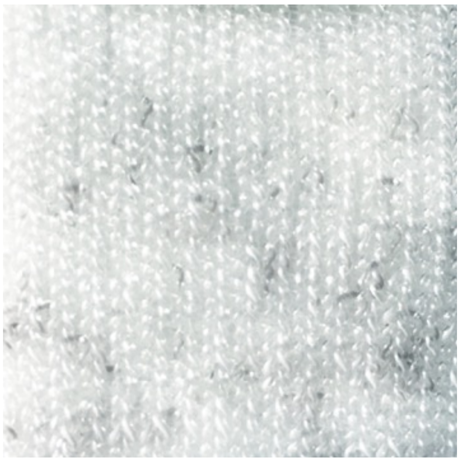
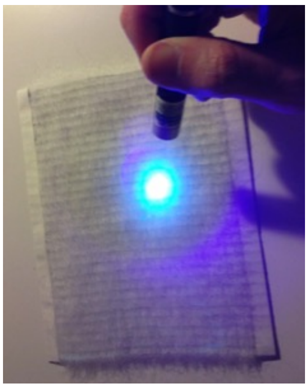


Figure 2.21

Figure 2.20 Thermochromic Swatch D under room temperature
Figure 2.21 Shrunken thermochromic Swatch D after colour changing

Swatch E is a soft off-white hairy swatch achieved by weaving the photo-luminescent Yarn D together with a fine Baby Kid Mohair yarn. Under normal lighting, the swatch appears as shown in Figure 2.22. Figure 2.23 and 2.24 show that when the swatch contacts with the ultraviolet laser, the Yarn D warps transform from light grey to light blue. The warps 'store' the stimulation from the laser and emit aqua green light in dark as Figure 2.25. Because of the hairy structure of mohair, the light emitted was scattered and a blur misty effect was achieved.


Figure 2.22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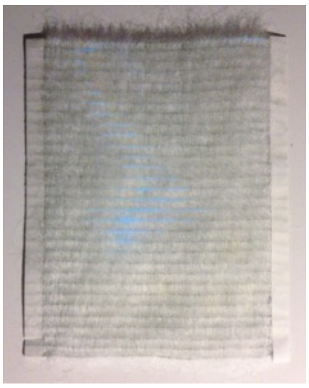
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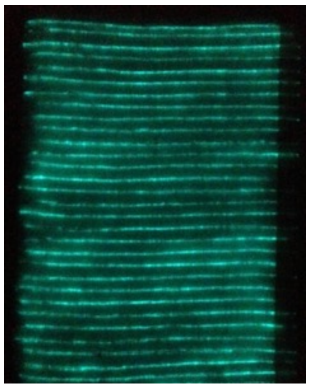
Figure 2.25

Figure 2.22 Photo-luminescent Swatch E under normal lighting
Figure 2.23 Photo-luminescent Swatch E being exposed to ultraviolet light
Figure 2.24 Photo-luminescent Swatch E in dim lighting after exposing to ultraviolet light
Figure 2.25 Photo-luminescent Swatch E in dark after exposing to ultraviolet light

Although the coated Yarn D is stiffer than original, it is flexible enough for crocheting. Swatch F (Figure 2.26) is a mix material crocheted piece. Similar to Swatch E, the coated yarn turned to light blue after exposing to ultraviolet laser and glows in absence of light (Figure 2.27 - 2.29). With the crocheted structure, the light emitting surface presents an artful texture rich visual effect in the dark.


Figure 2.26

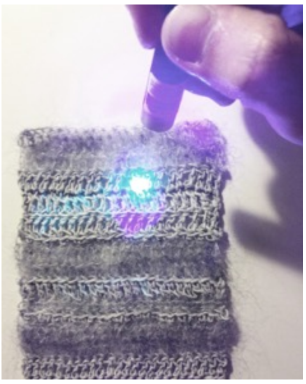
Figure 2.27


Figure 2.28

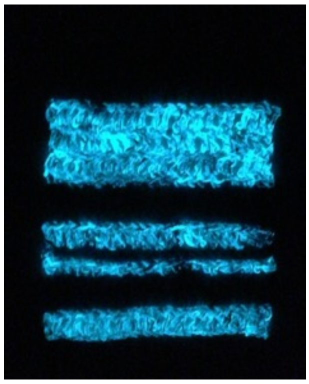
Figure 2.29

Figure 2.26 Photo-luminescent Swatch F under normal lighting
Figure 2.27 Photo-luminescent Swatch F being exposed to ultraviolet light
Figure 2.28 Photo-luminescent Swatch F in dim lighting after exposing to ultraviolet light
Figure 2.29 Photo-luminescent Swatch F in dark after exposing to ultraviolet light

In additional to weaving and crocheting, hand embroidery is another technique applied in swatch testing with Yarn D. Swatch G (Figure 2.30) is a photo-luminescent embroidered piece. A similar performance to Swatch E and F is achieved. Injected by the reactive property, the traditional textile technique is renewed.

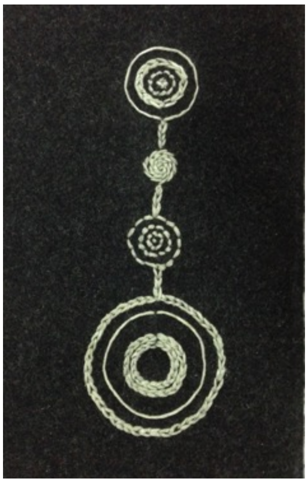
Figure 2.30


Figure 2.31


Figure 2.32

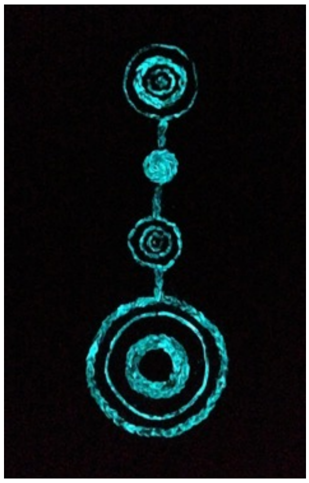
Figure 2.33

Figure 2.30 Photo-luminescent Swatch G under normal lighting
Figure 2.31 Photo-luminescent Swatch G being exposed to ultraviolet light
Figure 2.32 Photo-luminescent Swatch G in dim lighting after exposing to ultraviolet light
Figure 2.33 Photo-luminescent Swatch G in dark after exposing to ultraviolet light

	Developed Yarn Applied	Reactive Property	Textile Technique Applied
Swatch A	Yarn A	Thermochromic	Hand weaving
Swatch B	Yarn B	Thermochromic	Crocheting
Swatch C	Yarn C	Thermochromic, Thermo-shrinking	Cocheting
Swatch D	Yarn C	Thermochromic, Thermo-shrinking	Hand knitting
Swatch E	Yarn D	Photo-luminescent	Hand weaving
Swatch F	Yarn D	Photo-luminescent	Crocheting
Swatch G	Yarn D	Photo-luminescent	Hand embroidery

Figure 2.34 General details of swatches developed

Figure 2.43 summarises the general details of the tested swatches. The materials, equipments and techniques used in the trial applications were recorded in detail for evaluation. Systematic assessments are set to be conducted on both processes with parameters specifically set according to different textile techniques. With the data and evaluations generated through the assessments, a conscientious yarn and swatch development process will be conducted for the later stages of the research project.

4. Conclusion

This paper reviewed a number of interactive textile projects with focus put on environmental sensitive and responsive material applications. Secondly, presenting part of the preliminary developments of the ongoing textile design research project, the paper serves as a reference study and an introduction to interactive yarn development for textile crafts. Proven by the literature reviews and the experimental trials of interactive yarn and swatch, the research team believes that it is highly possible to further inject, more in-depth and sophisticatedly, the concept of interactivity into different tradition textile craftsmanships with adoption of environmental sensitive properties.

List of Figure

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