Techy Fashion: photonic fashion design process

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Abstract:

Photonic textiles with the ability to illuminate and adapt are innovative and highly interactive. It transforms inert fashions into communicative platforms where the viewer and the person who wears the outfit can actively interact without the use of verbal language. However, the integration of technology via electronics and the brittle nature of Polymeric Optical Fibres (POFs) in photonic textiles affect the way in which the fashion design is developed and created. It is vital to integrate considerations for the physical characteristics of the materials and technology within the creative process. Using three of the photonic fashion prototypes developed by the author and her research team as the main case study, this paper will study the evolving nature of the design process when developing photonic fashions. The fashion prototypes entitled Neo Neon, Totem and Urban Glow were developed over different research periods and by studying their design processes, the paper will investigate how the author and her team refine their process to adapt to both aesthetic and technological needs. The paper explores the development of these photonic fashions with consideration for the technology and design perspectives while most existing research is focused mainly on the technology aspects. The paper will discuss the differences when creative process involved when designing technology integrated fashions and conventional fashion design. The paper studies how technological and fashion considerations affect and support each other to develop innovative fashions which have the potential to be developed into communication enhancing products.

Keywords: Photonic Fashion Design, fashion design, photonic technology, interactive.

Article Classification: Research Paper

1. Introduction

Contemporary lifestyles which are fluid and transient have broken down the traditional perceptions of fashion design. There is a need for textiles which can adapt to the fast evolving needs of the users. Dynamic photonic textiles can be actively adapted and remotely controlled using convenient information technology devices. Such textiles enable users to customize their clothing via the emittion of different colors, patterns and frequency. The emotive power of color affects people across different regions (Xin et al., 2004) and have an impact on cognitive and affective functioning of individuals (Kwallek et al., 2007). In contrast to conventional textiles which remain inert, photonic textiles provide contemporary users with an alternative communication platform.

In recent years, illuminative textiles have emerged as an innovative and effective fabric for fashion. Light emitting clothing has been utilized by fashion designers to create costumes for international performers. The use of lights and colors had enabled the performers to create a visual spectacle and enhance the dynamic impact of their performance (Cutecircuit, 2006). In addition to appealing to the visual sense of the audience, the light emitting costumes also serve a highly functional purpose in which they increase the visibility of the artist when they are performing in large arenas.

Various applications of materials and technology have been found to create light emitting textiles for fashion. Such as, applications of LEDs on the surface or embedded under the base fabric (Black, 2010, Harold, 2006, Langeder and Dils, 2013), integrated electroluminescent materials (Wingfield, 2003) and the use of photonic textiles (Hashimoto et al., 2013, Bai et al., 2011). Although light emitting textiles which utilize direct application of LEDs and electroluminescent materials are effective, however the superficially applied light sources and components are obtrusive, they can be utilized for products which are meant for display or have limited contact with the body. In contrast, photonic textiles are woven with POFs and textile based yarns to create a pliable textile with good tactile quality. LEDs are connected to the fibre ends to serve as a light source, allowing the electronic components to be discreetly placed at different areas of the product with little contact with the user’s body. Photonic textile products provide users with a familiar sense of touch which is highly similar to conventional textiles and can be effectively developed into value added everyday products.

In order to gain a better understanding of the photonic fashion design process, this paper will discuss the fundamental technology, treatment processes, advantageous characteristics and the physical limitations of POFs. The weaving and the prototyping processes of the POFs to create interactive photonic fashions will also be explored. The design processes of three prototypes entitled Neo-neon, Totem and Urban Glow will be presented and discussed. The earliest creation was Neo-neon followed by the latter two prototypes. Each of the prototypes had been exhibited and the development of each design had contributed to the refinement and improvement of the subsequent creation. In conclusion, the paper will discuss the challenges and advantages of integrating technology and fashion design and recommendations for future research and developments.

2. POFs And Photonic Textile Technology

2.1 POF fibres and POF fabric

Light passing through an optical fiber was first demonstrated more than 150 years ago and developed using glass (Brochier and Lysenko, 2008). Since the development of POFs in the 1960s, POFs have been found to have many of the same advantages as conventional glass optical fibers. These include low weight, immunity to electromagnetic interference and multiplexing capabilities. Due to the fact that POFs are cheaper to manufacture and easier to process than inorganic glass fibers, they have attracted more and more attention in various industrial sectors. Meanwhile, POFs have some inherent good properties, such as high flexibility, low stiffness, and hence susceptible to textile manufacturing process. Therefore, they could be integrated into textiles to add new features.

POFs are composed of core material and cladding (Figure 1). Light transmits mainly within the core material according to the total reflectance principle, while the cladding layer protects the core material against mechanical damages.

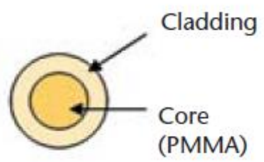

Figure 1: Cross sectional structure of POF

The critical angle θ_m of POF is the largest incidence angle for which refraction can still occur; in other words, for any incidence angle greater than the critical angle, the light will meet the condition for the total internal reflection, and the light is transported through the POF (Figure 2).

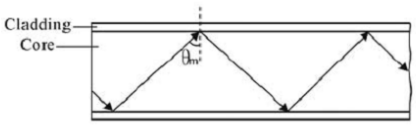

Figure 2: Light propagation in a straight POF

Photonic textiles refer to fabrics with integrated POFs. With appropriate light source and special treatments on the fabric surface, light can emit from fabric surface. The illuminating effect of photonic textiles greatly enhances the color and surface pattern of fabric, and therefore adds new features to textiles which are conventionally inadaptable.

2.2 Side-emission of light from POF

If the POF is bent, the incidence angle is changed and thus light with $\theta_1 < \theta_m$ will be partially refracted and light with $\theta_2 > \theta_m$ will be completely reflected (Figure 3). As a result, the light rays are only emitted on the outside of the bent section, and the light rays inside of the bent section still meet the total internal reflection condition (Wang et al., 2013).

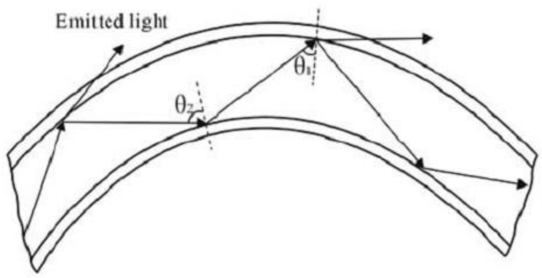

Figure 3: Light propagation in straight and bent POF

Side-emitting POFs can also be made in several other ways, e.g. by adding specific scatters or fluorescent additives into POF (Daum et al., 2002), by mechanically damaging the core-cladding interface, such as notching (Koncar, 2005), abrasion (Im et al., 2007), or sandblasting (Endruweit et al., 2008).

The principal disadvantage of macro-bending approach is the high sensitivity of scattered light intensity on the value of a bent radius. Particularly, ensuring that the fiber is sufficiently bent with a constant bending radius throughout the whole textile is challenging. If uniformity of the fiber bending radii is not assured, then only a part of a textile featuring tightly bent fiber will be lit. This technical problem becomes especially acute in the case of wearable photonic textiles in which the local textile structure is prone to changes due to variable force loads during wear, resulting in ’patchy’ looking non-uniform luminescent fabrics. The main disadvantage of the scratching approach is that the mechanical or chemical methods used to roughen the fiber surface tend to introduce mechanical defects into the fiber structure, thus resulting in weaker fibers which are prone to breakage. Moreover, due to the random nature of mechanical scratching or chemical etching, such post-processing techniques tend to introduce a number of randomly located obvious optical defects which result in almost complete leakage of light at a few singular points, making photonic textile appearance unappealing.

In this study, laser-engraving is adopted to remove part of the cladding of the POFs, in order for the light to be emitted along the surface of optical fibers (Figure 4).

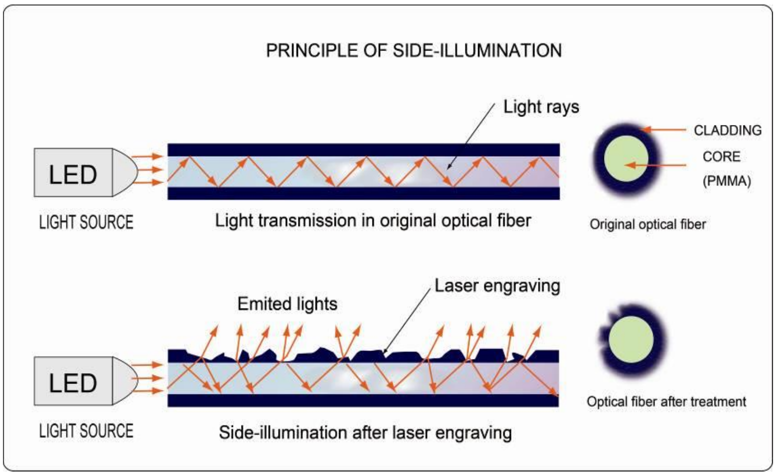

Figure 4: Principle of side-illumination by laser-engraving

The engraving is realized through a carbon dioxide (CO_2) laser. It is a kind of gas laser which emits light at a wavelength of 10.6 μm in the far infrared region of the electromagnetic spectrum. The laser engraving system requires different components, such as laser beam generation, beam delivery, work piece positioning and auxiliary devices, for the engraving. A basic laser machine system is shown in Figure 5 (Chryssolouris, 1991).

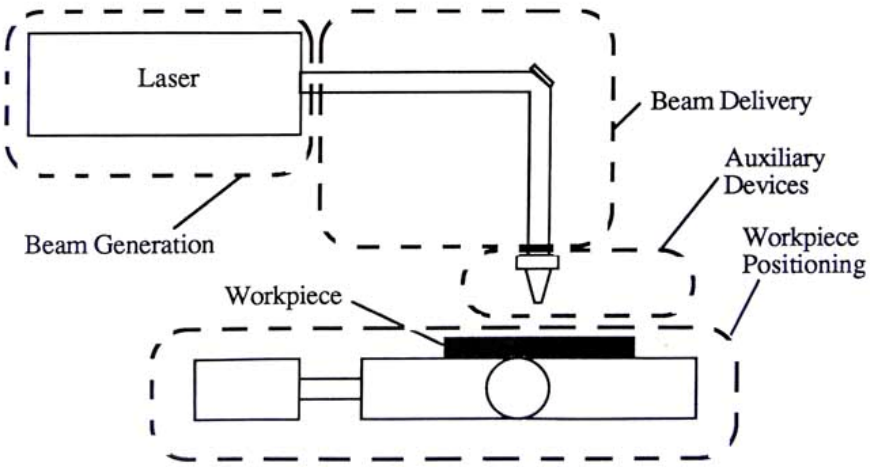

Figure 5: Basic laser machine system (Chryssolouris, 1991)

During the laser engraving process, the fabric is placed onto a platform, and a laser is directed to the fabric surface. The predefined engraving pattern is achieved by repeated laser scanning across the fabric surface. Laser power is determined by two parameters: resolution (in dpi) and pixel time (in μs). By altering the resolution of the designed pattern and the pixel time of the laser radiation, different engraving parameters can be achieved across the fabric surface and photonic fibers are damaged to different extents, and therefore different side-lighting effects of the photonic fibers are realized. The engraving process is accurately controlled by a computer program.

2.3 Weaving POFs to create POF textiles

The weaving method is adopted for integrating POFs into textiles in this research due to the fact that the grid structure of the weave is advantageous as it allows exact fiber arrangement and precise position determination (Abouraddy et al., 2007). Compared to knitted constructions, weave structures cause less damage to POFs, since the POFs are not bent extremely to create loops which are part of the knit structure. The construction of the woven fabric is based on three factors: (a) the size of the textile thread, (b) the woven pattern, and (c) the distance of parallelizing fibers. The distance between the parallel lying fibers influences the flexibility of the textile. To support effective light transmission and to avoid extreme bending of POFs in woven photonic textiles, open weaves should be used (Rothmaier et al., 2008).

Theoretically, POFs can be woven into the fabric via both the warp and weft directions. However, for the convenience of changing the yarns, POFs are usually woven in via the warp direction when using the hand weaving loom, while POFs are woven via the weft direction for a machine weaving loom. Moreover, studies on the luminosity of woven textiles in warp and weft direction demonstrated that POFs woven in weft direction showed better illumination results (Koncar, 2005, Harlin et al., 2003, Masuda Atsuji et al., 2006). For this research, the machine weaving loom was chosen because of its highly efficient performance. POFs are woven into the weft direction with other conventional yarns such as cotton and polyester. Otherwise, the tactile quality will be greatly reduced if only POFs were woven for the entire fabric due to the brittle nature of the fibres.

Woven fabric constructions can be limitless, however most structures are derivative from three basic weaves, i.e. plain weave, twill weave and satin weave. In this project, the photonic textiles were woven by plain weave and satin weave. The POFs were introduced as weft yarns, and the woven photonic textiles were produced using a loom that controls how the warp and weft yarns interlace. The warp yarns were cotton or polyester threaded under tension through the loom while the weft yarns (POFs) were inserted and pushed into place to make the fabric (Figure 6).

The plain weave possesses the simplest structure and is formed by yarns at right angles passing alternatively over and under each other. Each warp yarn interlaces with each weft yarn to form maximum number of interlacing. In most satin weave fabrics, each warp yarn floats over four weft yarns and interlace with the fifth weft yarn, with a progression of interlacing by two to the right or the left.

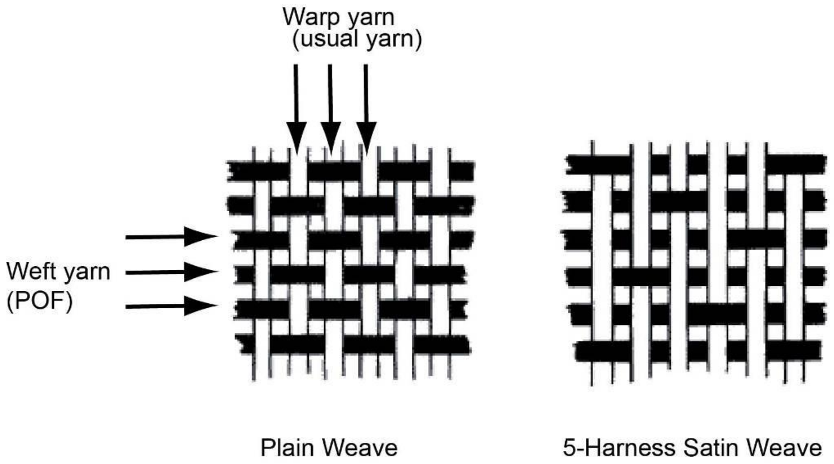

Figure 6: Integration of POF via the weft yarn in plain weave and satin weave structures.

By varying the weave structure and incorporating the photonic luminescence generated by the integrated POFs, different surface pattern, texture, color and luster can be created.

The plain weave photonic textile was produced on the CCI Automatic Sample Loom SL7900C. Figure 7, shows a fabric sample with small diamond structures. The fabric can illuminate revealing the intricate diamond structure. The content of fabric sample is 50% optical fiber and 50% cotton. Since the fineness of the optical fiber is close to the cotton yarn, the final photonic fabric sample can achieve a soft hand feel.

Figure 7: Photonic fabric with diamond structures.

Another photonic fabric sample in plain weave structure is presented in Figure 8. Some POFs are intentionally removed along the weft to form structure gaps in order to create an aesthetic design.

Figure 8: Photonic fabric produced by plain weave.

The researchers had also developed photonic textiles using Jacquard weaving technology (Bai et al., 2012). The photonic fabric was woven on the Dornier Weaving Loom PTV 8/J with the STAUBLI Jacquard Head JC6. Continuous geometrical pattern is designed in different scales.

The weaves are designed using ArahWeave® software. Figure 9 shows a photonic textile which was created using a combination of 8 end sateen weave, which allows many optical fibers to appear on the surface of the fabric and thus create a brighter illumination effect.

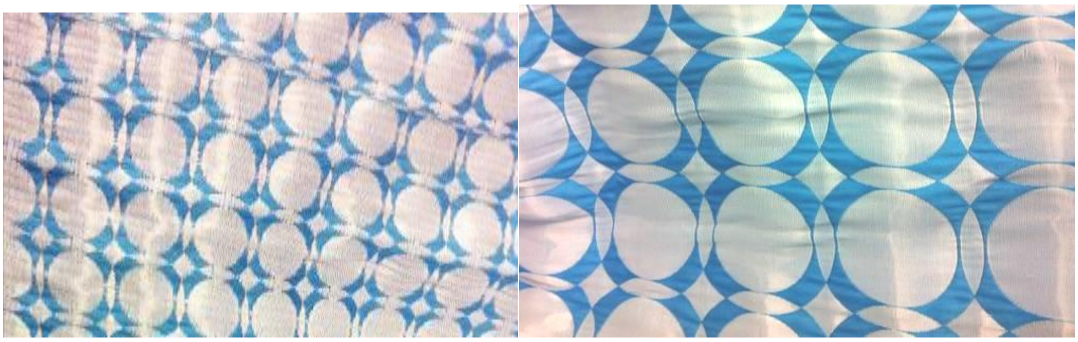

Figure 9: Photonic fabric produced by jacquard weaving

3. Integration of sensors to create interactive POF fashions

In order to further develop the interactive function of the photonic textiles, sensors were embedded into textiles to build up an interactive POF textile system. The function of sensors is to transfer physical phenomena into electrical signals which can be processed. In this research, electrical sensors, which can transfer touch and motion into electrical signals, are embedded into photonic textile to realize the interactive function of final prototype. When the embedded sensors detect the stimuli from viewer or wearer (touch or motion), the control system instructs the LEDs to change color in response to the stimuli, and therefore the fabric changes its illumination. In this fashion, the viewer and the wearer can interact without verbal language, and the wearer can also interact with clothing to alter the color and pattern. The clothing becomes a communicative platform enabling the wearer to interact with clothing as well as the viewer in terms of changing luminescence.

4. Photonic Fashion Prototypes

4.1 Prototype 1: Neo-neon

Neo-neon is a photonic fashion prototype which was developed in 2013. This prototype had been exhibited and had been collected by China National Silk Museum as part of its collection. Neo-neon was also part of a travelling exhibition entitled ‘Reflections of Time: the Art of Fashion in China’. The creative aim of neo-neon was to utilize fashion as a medium to explore the movement of time. It was inspired by the subtle relationship between light and time (Figure 10).

Figure 10: Inspiration and mood board of Neo-Neon (Tan, 2009)

This prototype combines neon green neoprene fabric with photonic textiles to create an outfit. The skirt was woven using the Jacquard loom to create three dimensional pleats which emits irregular rays of light thus exploring the movement theme of this creative work. The skirt can emit up to six different colors to adapt to the wearer's requirements. The color emission of the skirt can also be predetermined to allow gradual color changes thus allowing the wearer to evoke different emotive expressions over time.

Clothing necessitates a very high requirement due to the concern in safety, comfort and drape. The placement of LEDs, motherboard and the batteries were determined with consideration to the aesthetic design and the ergonomics of the body. It was critical to consider the design with the pattern and integration of technology at the initial stages of the design process. The process of development consists of numerous experiments which help refine and adapt the prototype from its initial design. The sampling and experimenting process allowed continuous revision and evolving development of a fashion prototype which is both functional and aesthetical qualities.

The prototype consists of a top, detachable peplum and a long skirt. The photonic textiles were used in the front panel of the top and the long skirt. LEDs serve as a compact and lightweight light source for the photonic textiles. Bundles of the POFs at the edge of the fabrics are connected to the LEDs and placed at the waist of the outfit. Although the power source and LEDs are small in size, the inclusion of such technological components will still add obtrusive bulk to the silhouette of the outfit. Therefore, frills were intentionally designed and placed at the detachable peplum to cover the interrupted silhouette of the garment. The LEDs were connected with POF bundles at the back waist of the garment as the hollow at the back of the body provides a natural concave to place the components without creating a very obvious bulge. The prototype can be powered by both A/C and D/C sources to adapt to static exhibitions and live catwalk fashion shows.

Figure 11: Initial rough sketch and production drawings for Neo-neon.

The entire photonic textile was engraved by laser to achieve an overall illuminating effect. At the upper part of the dress, a horizontal line was intentionally treated with higher power of laser to create a brighter line, which signs for the fractured pigment of time (Figure 12). The wearer can change the colors of the emitted lights by adjusting the controls and therefore customizing the outfit according to the requirements of the wearer, viewer and environment.

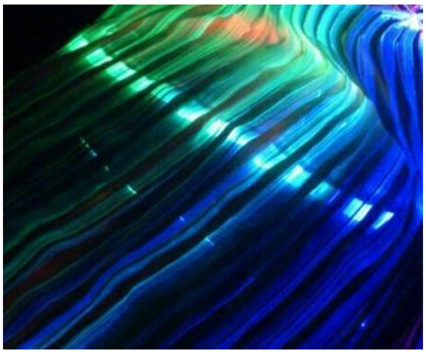

Figure 12 Lighting design of Neo-Neon

Figure 13: Neo-neon.

4.2 Prototype 2: Totem

Totem is a photonic dress prototype which was developed after Neo-neon in 2013. It was showcased at the Connect: Expand+ exhibition at The National Gallery in Bangkok Thailand in November 2013. The design inspiration of the design was taken from the symbolic meaning of totemic myths (Figure 14).

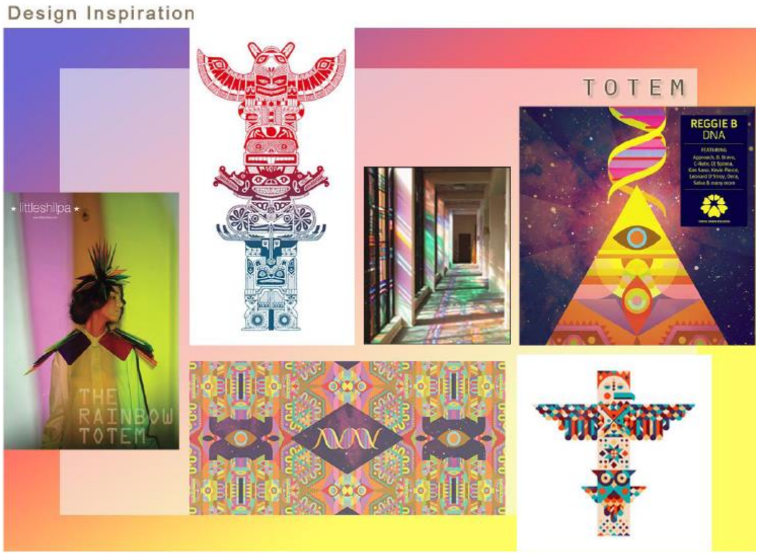

Figure 14: Design and inspiration board for Totem.

This design attempts to interpret ancient tribal symbols in a contemporary manner. To complement the photonic textiles, white synthetic leather were utilized to compose an abstract totem graphic of a hybrid facial pattern of an animal and human. Many different types of prints, colors and fabric combinations were experimented with to create a raised textured effect. The gradient digital print of the organza was selected to represent the diverse symbols of totemic culture. While the photonic textiles at the dress side panels symbolizes the advancement of technology which enriches the future of humanity.

Prior to the creation of the final garment, repetitive experiments with different fabrics and print effects were tested with actual fabrics and digitally. It was important to design a fashion garment which possesses ‘hanger appeal’ and to appeal aesthetically even when the photonic textiles were not lit.

The final outfit with dynamic illumination is shown in Figure 15. A loose fitting trapeze silhouette was chosen for the dress to allow more sufficient space to place the electronic components.

Figure 15: Totem with illuminating photonic textiles.

The placement of the electronic components had to be carefully considered, as the organza fabric panels are translucent, negligent placements will reveal the unsightly appearance of the electronic components. The electronic components utilized in this design are 1 motherboard, 6 LEDs with 3 LEDs illuminating each dress panel. The motherboard and the batteries are placed together in a box and placed at the center back panel of the dress. The components were placed strategically placed beneath the synthetic leather panels which cannot be seen by the viewer. That body will not be required to bend or move at that particular position thus the components will not hinder the wearer's movement.

To increase the interactivity of the outfit, a remote control in the form of an Android smart phone was integrated. The dress was connected to the smartphone using Bluetooth technology. In contrast to the previous prototype, the viewer can adapt the colors emitted from the dress by simply pressing on the smartphone. This function is particularly suitable for performace outfits as it can provide an effective platform for the performer and the audience to engage with each other in a non-verbal manner.

4.3 Prototype 3: Urban Glow

Urban Glow is a photonic textile cheongsam designed for The Hong Kong Museum of History for an exhibition of contemporary cheongsams in Hong Kong. The 2 outfits were exhibited in

Hong Kong and showcased in a fashion show in Taipei, Taiwan in conjunction for Hong Kong Week in November 2013.

Figure 16: Design and Inspiration board for Urban Glow.

Figure 17: Urban Glow

The creative aim of the designs was to reinterpret the traditional cheongsam into contemporary designs with incorporated illuminating technology. Traditional cheongsam elements such as the stand collar, Chinese knot buttons, slim fitting silhouettes with tapered hemlines and side slits are retained in keeping with the cheongsam style. Photonic textiles are innovative and visually exciting; however they primarily serve a decorative purpose in dark environments. To ensure that the photonic textile design possesses aesthetic purpose in both lit and unlit environments, all elements of the design such as the fabric design, style lines, materials are well considered to produce a quality design. The surface design of the non photonic textiles was inspired from Hong Kong's history and the Bauhinia Blakeana which is a symbolic flower of Hong Kong. Taking inspiration from Hong Kong history, the creative concept was derived from the evolving geographic characteristic from an antique map of Hong Kong's Victoria Harbor which represents the city's historical journey from a rural village to a contemporary cosmopolitan city. The textile design was digitally printed with symmetrical duplication of the bauhinia flower and the details on the historical maps were used as the basis to develop a graphic which was screen printed in metallic foil. The vibrancy of the digital print with the opulence of the foil print represents Hong Kong's dynamism. As the base color of the non-photonic fabric was grey, the POFs were specifically woven with a Lurex metallic yarn to create a grey photonic textile to match the printed fabric. The photonic textiles are integrated with sensors to enable the fabrics to change colors in tandem with the wearer's movement.

Figure 16: Heat-transfer printing using a heat press.

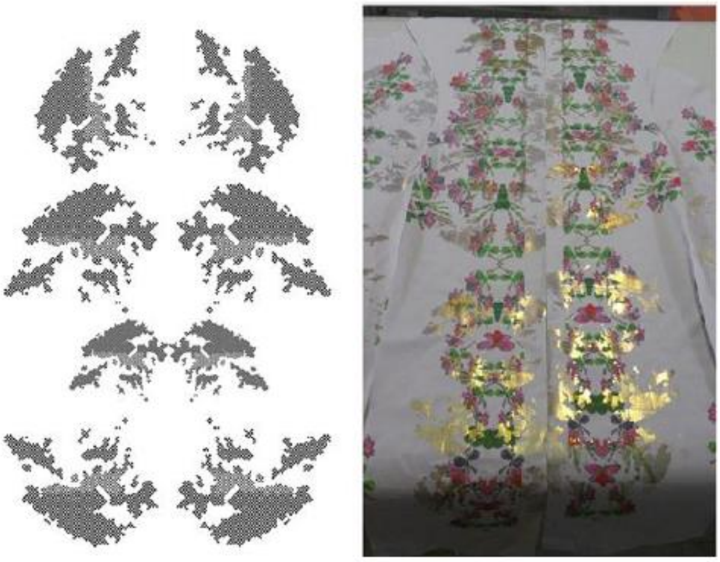

Figure 17: Screen print development for Urban Glow.

Due to the brittle nature of the POFs, the photonic textiles cannot be bent nor folded along the POFs' shaft. Bending of the POFs will cause breakage and light will escape from the break point and cause uneven light display. It was vital for the photonic textiles to be placed on areas which do not require the body to bend. Following initial design sketches, sample toiles of the cheongsams were created with cotton fabric to assess the viability of the design and to experiment with the placement of the components. The toiling process is vital in the fashion design process as it allows the designers to gauge the feasibility of the design and technology and consider the dimensions of the fabrics and the fit of the garment with the integration of the technology. After repeated experiments with the toiles, photonic textiles were placed on the sleeves of the cheongsam. These placements were selected because the wearer's body is not required to bend abruptly at these areas and thus will not cause breakage to the POFs and affecting the illumination.

The electronic components and their placements have to be specifically designed to adapt to the requirements of the design so as to ensure a seamless integration of technology. The design comprises of a one-piece dress which requires a motherboard, 1 battery serving as the power source and 5 LEDs with coupler cable glands and wires. All components are placed within the interior of the garment and cannot be seen by the viewer. As the main focus of the design is the sleeves, 2 LEDs were allocated at each sleeve while 1 LED is placed at apex point of the photonic skirt panel. A slim and compact battery similar to a mobile phone charging device is used in place of conventional batteries. The compact power source is lightweight and non-bulky, allowing it to be placed within the garment in a discreet manner. To ensure the weight of the electronic components is evenly distributed so as to avoid affecting the silhouette of the cheongsam, the motherboard and the power source are placed separately at the back panels near the hem of the dress. All components are placed in positions whereby the wearer can gain access to the components without the need to remove the entire garment. It is also convenient for the wearer to change power sources if the need arises.

This prototype was also showcased in a fashion show and as the models will be moving on the catwalk to showcase the designs, it was viable to explore interactivity between the wearer's movement and the visual effect of the garment. Inspired by the model's elegant catwalk movements, a GYRO sensor was selected for these two cheongsams. The sensor can detect the rotational movement of the wearer and change the colors emitted from the photonic textiles according to the turning movements. The model can actively change and control the emitted colors of the garment by simply changing her movements.

5. Design process and challenges

To design, develop and create interactive photonic textiles includes design investigation and development via the exploration of design themes, experimentation of materials, fabrication techniques, application methods, surface design, development of form and the production of prototypes. As the design process is a highly reflective process whereby designs evolve concurrently and simultaneously with the development of materials, processes and forms, it is valid to adopt the action research methodology in order to cater to the experimental nature of the design process. Action research addresses practical problems in a positive way, feeding the results of research directly back into practice, and its continuous cycle of development and change via research is beneficial to improve practice and resolve problem. Action research comprises of four main stages which works in a cyclic flow: look, think, act and reflect (Stringer, 2007). It allows the researcher to work in various directions of the design progression; processes can be continuously revised, repeated and refined, thus particularly suited for the exploratory nature of the design process. The flow of the research is consistent with the cyclic nature of action research whereby the researcher is able to retract or move forward to various stages of the process while "refining and defining the designs" (Tan, 2005). Based on these facts, action research strategy is employed in this research. As discussed before, the design of photonic textiles involves continuous improvement. The circular nature of action research is shown in Figure 20.

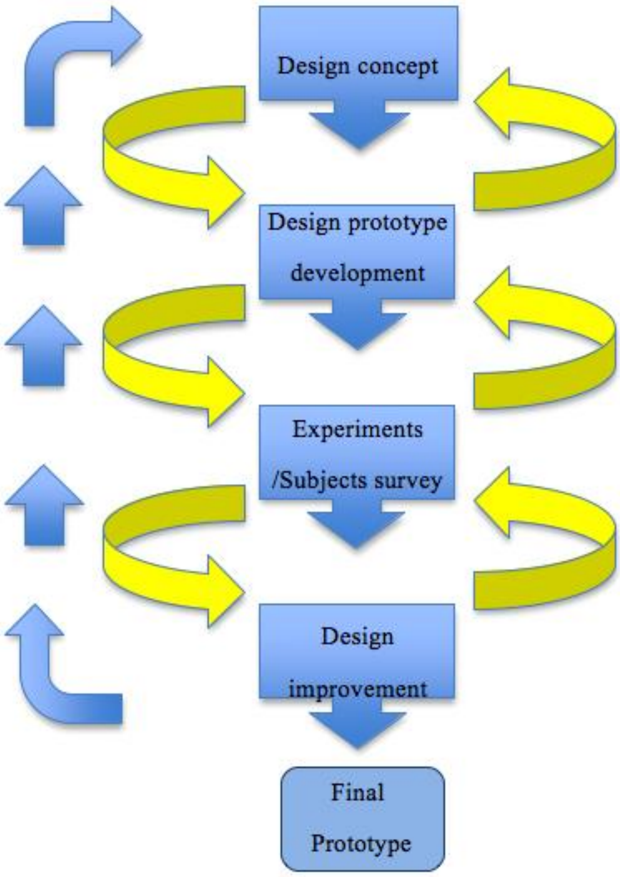

Figure 20: Circulated action research process

In the first step, a design concept is developed. This design concept is fundamental and paves the way for development of various prototypes. Based on the design concept, prototypes are produced. The fabrication of prototypes involves experiments with different materials, measurements of variables, and combination of a variety of technologies. Afterwards, experiments are performed to evaluate the functional performance of the prototype, and survey is conducted to assess the usability of the prototype. Based on the feedback from the experiments and surveys, the design is revised accordingly. This iterative cycle will be ended until the final prototype meets the predetermined requirements in terms of functionality, usability and comfort.

Conventional fashion design and the inter-disciplinary design process for Photonic textile fashion design is similar in the way in which it consists of a series of experiments and developments to create a final product. However, the photonic fashion design involves additional technological development at every stage throughout the entire design process. Fashion design methods and textile technologies must be used in combination with some cutting-edge technologies in other areas, like sensors, electronics, LEDs, etc. In the design framework, every stage is an interactive process between technology and design. The development of one part simultaneously affects its counterpart, and therefore the development at every stage is continuous process. For instance, during weaving the weaving should follow the weaving pattern and structural design, while the design of the woven pattern and structure should consider the technical issues of weaving optical fibers into a piece of fabric. It is important to utilize the weaving technique to create an aesthetic design yet taking account of the fragile and brittle nature of polymeric optical fibers. Design work needs to be continuously revised in accordance with experiments on the prototypes.

The design practice with consideration of both design and technology appears to be challenging to designers due to the fact that many technological components may not have been designed with aesthetics as priority and may prove to be challenging to integrate into products in an unobtrusive manner. Both the design and the technology have to adapt and support each other. It is also critical for the designers to possess both design skills and technological knowledge in order to achieve an effective product; hence an interdisciplinary approach is important. Designers need to continuously push the boundaries and come up with innovative design approaches with multi-disciplinary context.

6. Conclusion

Research which solely focuses on the technological aspect of smart textiles often result in highly functional products which may not have aesthetic appeal. Utilizing an interdisciplinary approach combining both aesthetic and technological considerations will contribute to the development of products with user appeal. In reference to the prototypes cited, such design processes are cyclic which requires the investment of time and labor to continuously refine both the functionality and design of the product. The design process requires greater flexibility as amendments are made to incorporate new findings from a wide range of practical experiments, theoretical research and aesthetic design developments.

In reference to the cited prototypes, the researchers had observed that it is the simplistic superficial application of technology onto a fashion garment may result in a design with a superficial gimmick which may attract attention in the short term. To ensure that the technology is not a simplistic ‘add-on’ it is important to consider the technology and integrate it into the fundamental entity of the product and with consideration to how users and viewers can easily interact with it. The photonic fashion design will not only serve the same function as conventional clothing but also as an interactive communication platform which will enable users to develop non verbal dialogues with viewers and the environment.

Further research should be conducted to improve the performance stability of the photonic products. Even smaller components and coupling techniques will contribute to the development of products which will have more intimate contact with the body. It will also be critical to develop POFs with greater flexibility so that photonic textile products can be exposed to realistic everyday use. Photonic textiles are sustainable as they are adaptable, they can be mixed and matched with different sensors and controls to accommodate different end users. The continuous research and design development of the technology and products will ensure its longevity within the market place. Photonic textile products possess a great potential to be developed into life enhancing products in the many areas such as interiors and healthcare which will improve the users' quality of life.

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