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Innovative Design of Polymeric Optical Fiber Fabric for Interior Textiles

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ABSTRACT

Polymeric optical fiber fabrics (POFFs) have been used in a wide range of applications, from smart clothing to medical products; therefore, it is interesting to note that there is a gap in the literature which explores the use of POFFs within the context of interior textiles. This research explores the use of illuminative interior textile surfaces as a multifunctional media that can enhance the interior environment via changes in colors, luminescence and surface design, and also act as a power-efficient light source for illumination. The development of POFFs involves several techniques, such as weaving, laser engraving, and integration of electronics. In order to obtain aesthetically pleasing surface designs and textures, and achieve favorable tactile quality, different materials are combined together. Surface printing and embroidery technologies are also adopted to enhance the surface pattern. A collection of life-sized photonic interior prototypes is created. The light sources of the prototypes are light emitting diodes (LEDs), which are considered energy saving and eco-friendly.

Keywords**:** Polymeric Optical Fiber Fabric, Illumination, Interior Textile Design

1. Introduction

Textiles form powerful interior components as they combine three strong design elements: the emotion of color, the impact of patterns, and tactile qualities sensed through visual perception and physical touch. With soft and comfortable tactility, textiles can offer physical advantages to interiors, such as sound absorption, privacy, comfort, enhanced safety and aesthetics, and can also set a mood, establish a theme, and secure an ambience to create an enhanced interior environment.

In recent years, consumers have been seeking a Lifestyle of Health and Sustainability (LOHAS). Eco-friendly products, which are sustainable, energy-saving, and low-carbon, have gained increasing popularity. On the other hand, people also want their interior textiles and furnishings to be fashionable and customizable to their preferences. There is a growing demand for interior textiles to be adaptive and flexible and an eco-friendly tool to help reduce the emission of carbon. Consumers demand interior textiles which are multifunctional (Nielson, 2007).

With the emergence of optical fibers, textiles engineered with the ability to illuminate are now possible. Photonic textiles with changeable and tunable colors can present a pleasing visual effect and customized interior environment to the user, and therefore greatly enhance the interior environment. Meanwhile, photonic fabrics can also be used as a mood-enhancing source of illumination.

Polymeric optical fiber fabrics (POFFs) have been used in a wide range of applications, including optical fiber displays and textile illumination devices (Harlin et al., 2003; Koncar, 2005). Fashion and interior products that employ luminous fabrics have also been commercially available in the market (LUMINEX, 2003). In most cases, a multiplicity of polymer optical fibers are integrated into textile structures connected to a light source at the fiber ends. LEDs (Graham-Rowe, 2007) or powerful light sources (Thiele, 2003) are used for photometric applications.

This study attempts to apply POFF in the design of interior furnishings. Different techniques which are involved in the development of photonic textile are introduced. A collection of life-sized prototypes is presented.

2. Approaches

2.1 Design Concept and Theory

The objective of the design is to develop a photonic fabric, and adopt this fabric in the construction of a collection of interior furnishings, including a cushion, wall hanging, etc. With an illuminative effect, the furnishings can create two different interior environments during the day and the night (Figure 1).

The design inspiration is derived from ancient Chinese pottery (Figure 2). Chinese painted pottery originated in the Neolithic Period about 7,000 years ago. The unadorned nature, shapes and textures represent the sophisticated nature of ancient Chinese civilization.

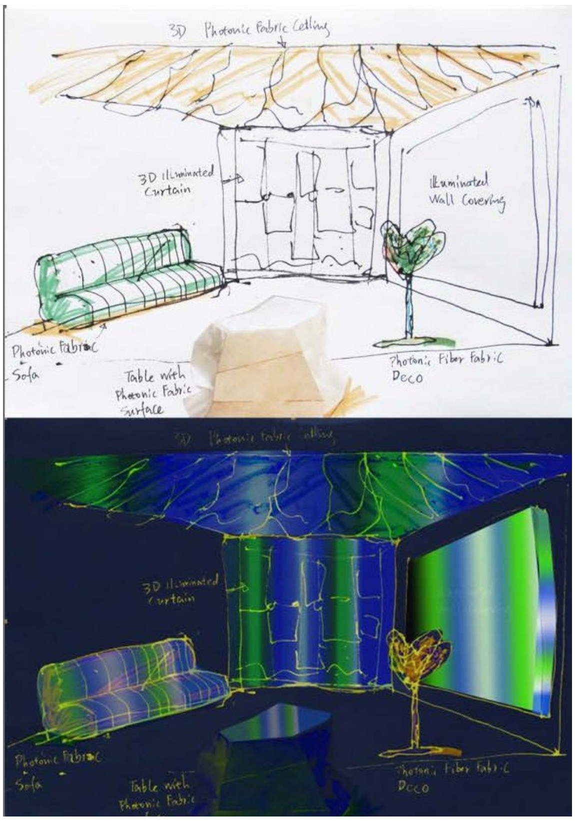

Fig. 1. Design sketch- illuminating interior furnishings in different environments

Fig. 2. Inspiration and color mood

The colorful patterns on the painted pottery represent the wisdom of the ancient Chinese civilization. Geometric patterns and drawings of animals and human faces are commonly found on these ancient potteries. These patterns are symbolic of the ancient Chinese culture. They are strange yet familiar, realistic yet abstract, and unadorned yet precise.

All of these elements in the ancient Chinese pottery represent two different characteristics: an unadorned nature and mystery. The design theme of the illuminating interior textile was inspired by these two characteristics from the ancient Chinese pottery. The design attempts to interpret the colors and patterns of ancient painted pottery from a contemporary perspective. A series of earth-tone cotton fabrics and yarns were selected for the development of the POFF and a collection of interior furnishings.

2.2 Weaving

In the application of optical fibers, polymeric optical fibers (POFs) are often used due to the fact that they are more resistant to textile manufacturing processes and have higher flexibility and low stiffness, compared to glass fibers (Kuzyk, 2006). Therefore, poly (methyl methacrylate) (PMMA) optical fibers with a diameter of 250 µm are used in this study.

Weaving technology was adopted for integrating

POFs into the textile. The grid structure of the weave is advantageous as it allows exact fiber arrangement and position determination (Abouraddy et al., 2007). The construction of the fiber grid was based on three factors as follows: (a) textile thread that is small in diameter and flexible, (b) the woven pattern, and (c) the distance of the parallel lying fibers. The distance between the parallel lying fibers influences the flexibility of the textile. The light emission on the POFF surface is decreased by tighter weaves and increasing diameter of the fibers. To support effective light transmission and avoid hard bending of POFs in woven POFFs, open weaves should be used (Rothmaier et al., 2008). Studies on the luminosity of woven textiles in the warp and weft directions demonstrated that POFs woven in the weft direction show better illumination results (Harlin et al., 2003; Koncar, 2005; Masuda et al., 2006).

By varying the weave structure and incorporating a photonic luminescence generated by the integrated optical fibers, different surface patterns, textures, colors and lusters can be created. A weaving loom (CCI SL7900C automatic sample loom) was adopted for the production of the optical fiber fabric (Figure 3).

In this study, optical fibers are introduced as the weft yarns. The warp yarns were cotton threaded under tension through the loom; the weft yarns (POFs) were inserted and pushed into place to make the fabric. Figure 4 shows the POFF with a plain weave structure. Laser engraving technology, which will be discussed in Section 2.3, can be applied onto the woven photonic fabric to achieve a surface illuminating effect.

Fig. 3. Integration of optical fibers into fabric, processed on a weaving loom

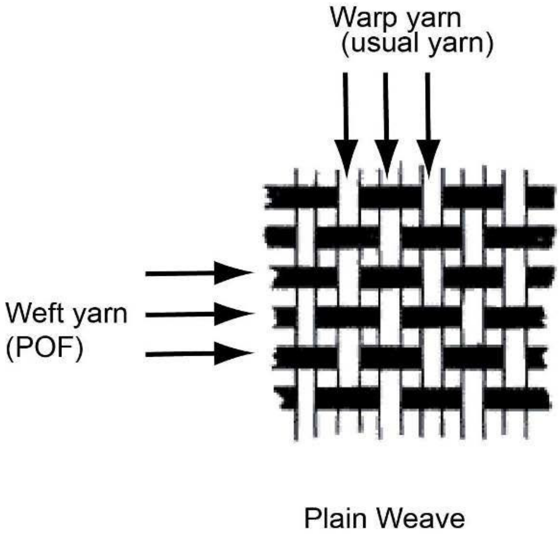

Fig. 4. Plain weave structure with integrated POFs as the weft yarn

2.3 Laser Engraving

The main role of optical fibers is to transmit light or optical signals onto a specified spot. However, if the cladding of the optical fiber is partly damaged by physical or chemical treatments, the light leaks out from the damaged spot and side-lighting will occur. The side illumination of fabric will greatly enhance the surface color and pattern, especially in dark environments.

Traditional treatments that promote side illumination involve thermal, physical or chemical damage of the cladding of optical fibers. However, these treatments are very rough and difficult to control, and only simple cutting patterns can be obtained. In this research, laser engraving is employed to induce side emission of light (Figure 5). Laser engraving is a technology that uses a high-power laser to cut materials, and the engraving can be precisely controlled by a computer. A laser engraving machine, Marcatex Flexi-150 (GFK), was adopted. The fabric was placed onto a moveable platform, and a laser was directed onto the fabric surface. A predefined engraving pattern was achieved by repeated laser scanning across the fabric surface. By altering the resolution (in dpi) of the designed pattern and the pixel time (in μs) of the laser radiation, different engraving parameters could be achieved across the fabric surface, and optical fibers were damaged to different extents, and therefore different side-lighting effects of the optical fibers were realized. The engraving process was accurately controlled by a computer program.

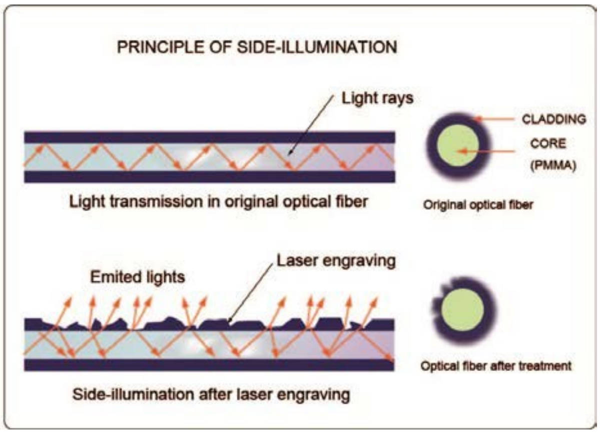

Fig. 5. Principle of side-illumination through laser-engraving

2.4 Embellishment

In order to enhance the aesthetic and tactile quality of the photonic fabric, patterns on ancient painted pottery were reproduced onto the fabric surface by embroidery and printing.

2.4.1 Embroidery

Basic machine embroidery is limited by the presser foot of the embroidery machine to make regimented stitches in a vertical direction while free style machine embroidery works with a special presser foot which allows the material to move in any direction thus creating a more organic and fluid effect. A wide variety of embroidery stitches can be utilized in different materials to create various colors, texture, patterns and structures. They can be used for further experimenting in terms of various scales, stitch lengths, colors and materials to create a range of visual and tactile effects.

In this design process, traditional Chinese patterns were embroidered onto POFF by using an industrial embroidery machine (Figure 6). The embroidery enriched the layers of the surface and enhanced the tactile of the POFF. Since the POFs are easily damaged, the speed of the stitches had to be controlled. A special stitching method was also selected, which created a unique embroidered look. The thread color was cohesive with the color of the POFF.

Fig. 6. Embroidery on POFF. The pattern is inspired from motifs on ancient pottery

2.4.2 Screen-printing

Screen-printing (Figure 7) is a viable technique to apply patterns onto POFFs as the low impact application will not affect the rigid nature of the POFs and compromise the technological functionality. This can create a variety of effects and textures, and enhance the overall aesthetic of POFFs in both dark and bright environments.

Fig. 7. Screen-printing on POFF

Figure 8 shows an illuminated effect on POFF. The patterns are abstracted from semiotics on ancient pottery.

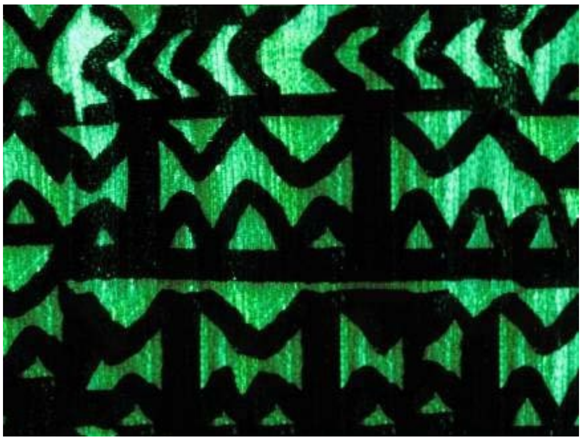

Fig. 8. Illuminated effect on POFF

2.5 Integration of Electronics

In the design of photonic interior textiles, the usability of the final products needs to be taken into consideration. It is very important that the electronics, including light sources and control devices, are unobtrusive. In addition, most of the interior products need to be environmentally-friendly, lightweight and durable, and therefore LEDs with RGB colors were used as the light source of the photonic fabric. LEDs with RGB colors can generate different colors as required, and the color can be changed and tuned by fine-tuning the primary colors. Groups of optical fibers were bundled together and then coupled with LEDs with predetermined sequences. Since the photonic fabric had already been treated by laser engraving, the light of the LEDs can leak from the damaged cladding of the POFs, and therefore side-illumination from the surface of the fabric is obtained.

Ultraviolet bonding technique was adopted in coupling the LEDs, which can maximize the lighting efficiency and reduce the coupling loss. First, all of the optical fibers were grouped into several bundles. Then, the ends of every bundle of optical fibers were adhered to an LED with optical glue which would not significantly affect the light intensity at the optical fiber ends, while still secure a good connection between the optical fiber ends and the LEDs. In order to solidify the optical glue, the joints were then exposed to ultraviolet radiation for several minutes. All of the controlling electronics of the LEDs were docked on a motherboard (Figure 9). The whole electronic system is lightweight and mobile. At the same time, the LEDs are energy saving and a power-efficient light source for illumination.

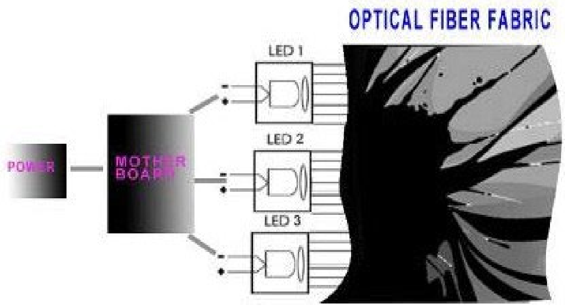

Fig. 9. Schematic diagram of the POFF system

3. Results

"Chinois Photonics" (Figures 10 and 11) is a collection of furnishings that use POFFs. The collection was exhibited at the Future Photonics exhibition (Bai et al., 2011). This collection includes life-sized cushions and wall hangings which are made from innovative illuminating textiles.

Fig. 10. "Chinois Photonics" cushions in the daytime

In contrast to the unchangeable nature of traditional interior textiles, the innovative photonic textile can present two different colors during the day and night. In the day, they show the original color of the textile with printing and embroidery (Figure 10). The earth tone color palette represents the ancient pottery in a harmonious and cohesive manner, showing a return-to-the-original-nature style. In the dark, strong block colors are illuminated from the textile, providing a stark contrast to the other version (Figure 11). Meanwhile, the POFs, LEDs and other textile techniques are integrated into the design to enrich the color and pattern of the interior textile.

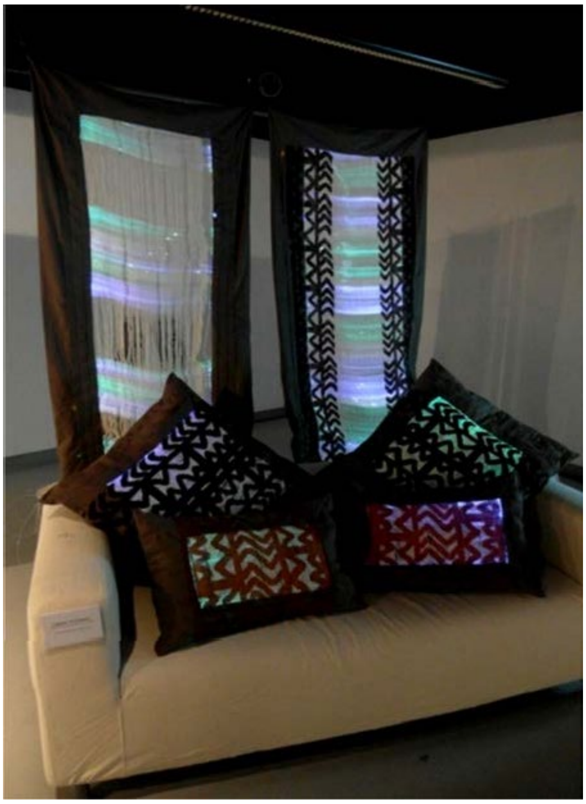

Fig. 11. “Chinois Photonics” with illuminating effects

What is more, the illumination from the photonic textile can be an alternative light source that replaces conventional lamps in the dark. The coupled LEDs consume very little electric power (around 0.06 W/LED).

4. Conclusions

This research explores the design and development of a fashionable and innovative interior textile with consideration of the environmental impact of the final prototype. The researchers are successful in weaving optical fibers with cotton yarns to create a positive hand feel and good flexibility as demonstrated by the draped shape of the artwork. The researchers are also successful in using laser-engraving technology to cut the fiber surface to allow emission of light at the engraved areas along the length of the fiber. Traditional surface printing and embroidery techniques have successfully enhanced the surface texture and design aesthetics without compromising the technological functionality of the photonic textile.

The engineered prototypes can enhance the interior environment, and help reduce the carbon footprint by consuming less electrical energy. The prototypes have the potential to be utilized in value-added products, which can enhance the quality of life.

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