

Design and Applications of LED Textiles

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Keywords: Green Textile, LED, Textile Design, System Design

Abstract. As a new and efficient light source, LED has the advantages of long service life, low power consumption, small volume, light weight, rich color and fast response. Therefore, LED seems apparently quite suitable for functional apparel design, and becomes an important item of development, exhibition and promotion for research institutions and the clothing industry. In the recent years, the development trend of textile application of LED is changed from simple light bulb and light bar to the emergence of new material, including soft packaging, optical fiber, LED yarn, and organic light emitting diode. This paper describes components and systems of LED, textile application material and using method, concept illustration and design idea of some selected application cases. The purpose of this paper is to spread the knowledge of function, esthetics and practical value which displayed by the LED application in clothing, and improve both customer acceptance and market potential of luminous dresses in the clothing market.

Introduction

In accordance with the development of scientific products, many emerging materials have gradually been applied to textile design and application, such as LED, heating element and solar cell. Due to characteristics of photo lighting and energy saving, LED was used in display, advertisement and signal in the early stage, and extended to backlight module and lighting at the present stage, as well as involved to costume design in recent years [1]. The design of traditional costumes focuses on practical requirements of daily activities and meets inner beauty desires of human nature. The design of modern costumes has more selections of applicable elements, and can combine with electronic components, thus the clothing appearance with additional features make the costumes gradually convert to another fashion style. By using the unique nature of LED, the costumes will exhibit the characteristics of functionality, intelligence and artistic value. Therefore, the design and application of LED textiles has aroused extensive attention of the garment industry and avant-garde consumers, which shows important development potential and application value in the future.

For the applications of LED in textile design, small lamps and light strips were used in the initial stage [2, 3], followed by Philips with soft packaging products [4], and later the side-emitting optical fibers began to be introduced and developed to more diversified design concepts [5-8]. Recently, Taiwan Textile Research Institute launched a novel product, LED yarn, which provided a new material for luminous fashion design and had held several presentations [9].

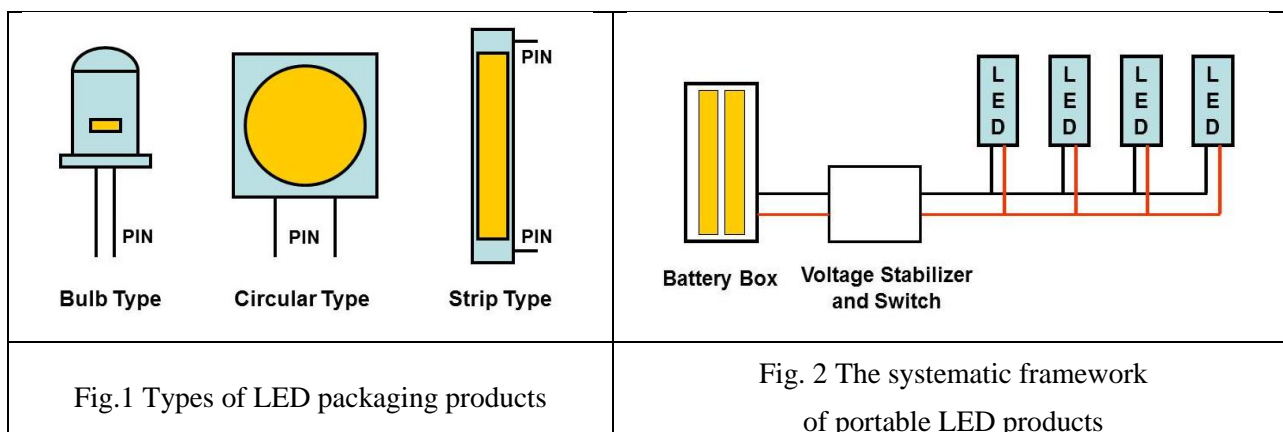
This publication contains research and analysis of applications of LED in textile design, describes components and systems of LED, material and methodology for textile application, and proposes some practical concepts and ideas for textile design. The purpose of this study is to promote the utilization of LED in both textile products and potential market, and provide a design reference for those interested to be a luminous textile designer.

Components and Systems of LED

Light-emitting diode (LED) is a kind of semiconductor electronic component which uses low voltage DC electricity to induce luminescence. Hewlett Packard Company started to commercialize in 1960s, mainly for the red and yellow LED components. LED was initially used in various instruments for digital and text display, and then extended to advertising signboards and indication signs. Due to Nichia Chemical Company invented the blue LED in the era of 1990s, the white LED composed by complementary colors had appeared in the market for lighting fixtures. Currently major commercial application of LED is the backlight of LCD screens.

The advantages of LED are higher energy conversion efficiency and longer service life, which can be used up to 30,000 hours in an appropriate environment. In addition, LED is resistant to shock and impact, is small for easy assembly, and can achieve high flicker frequency with short reaction time. As for the disadvantages of LED, LED is a kind of point or surface light source, thus optical lens or the other methods are needed for producing three-dimensional light source. The color rendering index of LED is poor with a feeling of unusual color, and the long-term use may have an impact on vision. Additionally, the luminous efficiency of LED will be affected by high temperature, and the life expectancy will also be shortened, therefore the better hot dissipation is needed to be design for protection. Besides, the higher cost of LED results in more initial investment budget.

In practical applications, the packaging of LED chips requires the use of fluorescent powder and epoxy resin. As shown in Fig. 1, the low-power bulb-type product was assembled in the early stage, and the types of circular plate and long strip were then appeared for high-power application. The finished packaging product used pins to connect electricity for generating the luminous effect [10].



LED requires DC as the electricity source. Although a low voltage of 2.5V can drive the current flowing through LED, the light flux will be too small to be useful. In general case, it needs 3.5V to induce 350 mA to achieve a rated amount of light emission. The voltage cannot be too high, otherwise it will induce more current and cause temperature rising to damage or attenuate the performance of LED. If multiple LED are used, the series or parallel circuits should be applied [11]. An overall system of LED includes packaging lamps, connecting circuits, switches and power sources. As shown in Fig.2, in the case of portable electronic

products, batteries can be selected instead of the power supply, and a voltage regulator should be added to stabilize the variation of voltage.

Material and Method of Textile Utilization

When using LED in textile design, in addition to firmness, beauty and practicality, the compact size should be considered for easy to carry, the flexibility is suitable to avoid the human body discomfort, and the washability is needed to satisfy the requirement of reuse. Based on the above factors, the traditional bulb-type LED products are not adequate for direct use in clothes, but can be applied in hats, shoes, backpacks and purses, as these items do not cause discomfort when wearing, and easy to separate for washing. The LED products, which are currently used in textile design, include soft packaging, optical fiber and LED yarn. Organic light-emitting diode (OLED) is also suitable for textiles, but this technology is not mature enough for commercial application [12].

Philips had ever developed new type of LED packaging as shown in Fig. 3, which LED chips were arranged in preset patterns on a soft substrate, such as stars and hearts, and adopted soft polymer material for packaging [4]. The completed package had the property of flexibility and then fixed to the inside of clothes. In addition, there was a detachable battery box with switch installed in the lower inner side of clothes. The clothes would issue star-shape or heart-shape light as long as the switch was pressed.

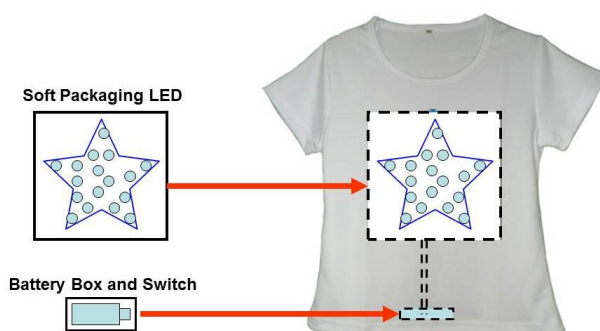


Fig. 3 A luminous sport shirt equipped with soft packaging LED

A Taiwan company GDH has worked on research, production and promotion of plastic optical fiber used for textiles since 2005 [13]. The fabric made by optical fiber has the characteristics of light, soft, flexible and luminous, and can be applied to a variety of clothing and accessories. The optical-fiber fabric is a kind of side-emitting light source composed by fine plastic optical fibers and various textile fiber yarns, and it could weave into planar fabrics. The luminous effect is induced by using LED light along with optical fibers. Such fabrics will show original colors of yarns in the day time, and can emit lights at night time with different colors depending on the selection of LED.

The principle of optical-fiber fabric is shown in Fig. 4. Side-emitting optical fibers and specific reflective colored yarns can be woven into a fabric, and each of optical fiber strands will be connected to LED light source. If turn on a power to trigger LED, the light will go forward along each optical fiber strand resulting in

illumination of whole fabric. A dancer's costume using the optical-fiber fabric is shown in Fig.4, it can cause the costume glow to produce the brighter and luster effects for performing on the stage.

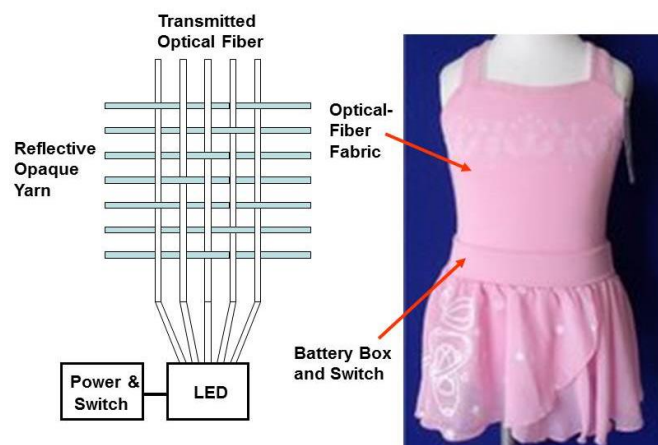


Fig 4. Optical-fiber fabric and a dancer's costume made by optical-fiber fabric

The LED yarn was developed by Taiwan Textile Research Institute in cooperation with manufacturers of electronic products [14]. This product has the characteristics of flexibility, abrasion resistance and strength with the potential of market application. The LED yarn is using a series of LED chips embedded in an electrical conductive fiber yarn to form a light emitting element. In order to ensure insulation and increase strength, a highly transparent resin is selected for being encapsulated material. A mass production method has been developed to reduce the cost of LED yarns, thus this product can be supplied by roll base with an outer diameter of 2.5 mm. The maximum current consumption is 240 mA/m when the input voltage is DC 4.5V, and the service time is about 20,000 hours.

The structure of LED yarn can be seen in Fig. 5. The model number of LED chip is SMD 0603 with the dimensions of $1.6 \times 0.8 \times 0.4$ mm, and the spacing between chips is 20 mm. There are five colors of LED chips for selection, which are white, red, blue, green and yellow. The chips are encapsulated on a conductive fiber, and then coated with an optically transparent resin to form a LED yarn. LED yarns can be sewn on appropriate locations of clothes, and connected to battery boxes, switches, and circuit boards. Therefore, one can make the start switch when LED light is needed, showing the beauty of high-tech fashion.

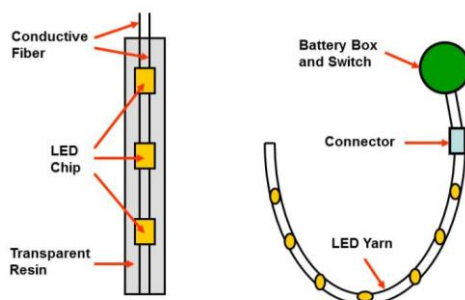


Fig. 5 The structure and the product of LED yarn

Concepts and Examples of Textile Design

LED is a kind of light emitting element and can be added for the effect of luminous textiles. Using LED for fashion design, components and system should be fully understood at first, and then more importantly it must be matched the feature, functionality and beauty of the clothes. Furthermore, the assembly of LED components should not cause discomfort to the wearer, nor impede the original function of clothes, or make the wearer's daily actions being interfered or affected. The shiny parts, patterns and amount should be carefully considered and design, otherwise not only the beauty cannot be created, but also the weird feeling will appear. For example, a full dress or the most parts of the dress has emitted high-brightness lights, which will generate the effect of lantern. It likes to put the body in a lantern and makes a self-defeating dilemma.

There are several types of LED components which can be applied for textile design, and related features and integration methods are described as follows:

- LED bulbs and strips – Small bulbs and strips are traditional LED products with low cost and easy access. Because this form of components are generally not suitable for washing, the method of adhesion or simple suture is used to apply for combination of LED components and clothes with a detachable possibility.
- Soft substrate packaging – Design and production of such components need support from professional manufacturers. The cost is more expensive and the product is more suitable for mass production. The entire structure can be installed inside of clothes. The luster decoration of preset patterns is very vivid and shows good results.
- Optical-fiber LED fabric – Optical fibers can be used with the traditional yarn to create a special fabric by weaving technique. After cutting to make a dress, it is very suitable for stage performances, bridal clothes and banquet costumes.
- LED yarn – It is a recently developed product. The luminous effect is quite good, and the durability is also good enough for washing with water. LED yarn can be sewn on the clothes, thus the combination process is simple.

Based on the characteristics of LED components, several design concepts are developed and shown in Fig. 6. Fig. 6(a) is a LED necklace. LED chips must be encapsulated into translucent resin beads, and then concatenated into a circular conductive string. A decorative agate charm is attached at the bottom of the strip, and a small battery with a press-type switch is installed at the top of the strip. When the wearer is at a party place, the switch can be started to make the necklace blink and continuously emit soft lights. Fig. 6(b) is a LED scarf. Three LED yarns are stitched on the scarf, while two yellow yarns are at the both sides and one white yarn is at the middle of the scarf. At night, the switch can be started to light LED yarns, and it may increase beauty and remind people and cars for attention. This effect will enlarge the wearer's identification and security.

Fig. 6(c) is a LED raincoat. A red heart logo with yellow square frame made by LED yarns is attached on the backside of the raincoat, and a battery box with a switch is located at the bottom side of the logo. Such raincoat can be used by children, pedestrians and motorcyclists for the effect of protection. In a rainy day or night, LED yarns of the raincoat will display red light warning to remind the rear cars not to close for

ensuring the safety of wearers. Fig. 6(d) is a LED jacket. A pattern-type optical-fiber fabric is sewn on the upper side of left front part of the jacket, and light guiding strings and a battery box are placed inside the jacket. Since the battery box has a LED chip, the LED light will emit along with light guiding strings into the optical-fiber fabric and make the pattern light for showing decorative and aesthetic functions.

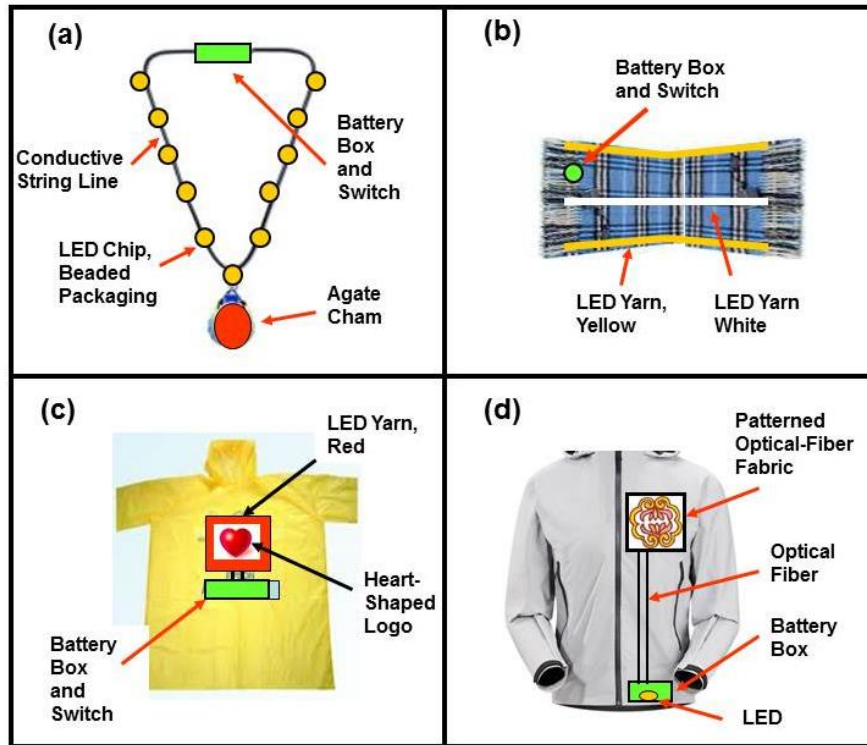


Fig. 6. The design concepts of LED textile:
(a) necklace, (b) scarf, (c) raincoat, (d) jacket

Concluding Remarks

According to the analysis and discussions of this research work, the following conclusions can be obtained:

- Due to excellent optical properties and rapid technology development, LED has gradually become a new material for textile design. Research institutes and the textile industry are trying to learn and develop with constantly publish new products and attempt to commercialization.
- Although the traditional LED bulbs and strips are simple and cheap, the emerging optical-fiber fabrics and LED yarns have become the focus of development.
- In order to promote LED components to be used in the textile industry and market, it needs creativity of more fashion designers and participation of more apparel manufacturers. Thus, the training effort for fashion designers to be familiar with the application of LED components in textile design is very important.
- In the future, the LED textile will combined with the trend of intelligent electronic evolution to access a wider range of applications.

Acknowledgements

This work was financially supported by the National Science Council in Taiwan, R.O.C. The project title is “Theoretical Analysis and Application Study of LED on Textile Design”, the project number is NSC 102-2410-H-468-022, and the working period is from August 2013 to July 2014.

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