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Design, Fabrication and Evaluation of a Multifunctional Jacket with Optoelectronic Effects

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Abstract. The modified innovative product design and development method has been developed and used for a design work of innovative and multifunctional jackets with optoelectronic technologies in a previous study. There were six items of key design themes were found out, including practicality, aesthetics, portability, washability, multifunction and composability. In this study, a design strategy and solution was proposed and a multifunctional jacket with optoelectronic function was completed. Finally, a survey with questionnaire was executed and analyzed for evaluation and verification of the design achievement. According to the consequence of data analysis, the performances of a new innovative and multifunctional jacket of this study are better than those of a traditional jacket.

Introduction

Smart and multifunctional textiles have been becoming a developing trend in recent years. Among these textiles, the optoelectronic textile indicates apparels using special components for displaying photoelectric effects and functions. The most popular optoelectronic elements are LED lighting and solar power. These elements can provide functions of glorious modeling, light-emitting display, security alerts and power supply. The power supplied by solar cells can be used to drive LED, electric heating pads, acupuncture vibrators and massage pads, as well as to charge consumer electronic products, such as mobile phones, digital cameras, and music players.

There are many kinds of apparels can be installed with optoelectronic components, such as jackets, suits, vests, sweatshirts, pants, bags, shoes, gloves, raincoats, etc. During recent years, there are some new optoelectronic materials which have been developed for using in apparel design, such as optical fiber, LED yarn, colored solar cell, etc. [1-7].

In a previous study [8], a modified innovative product design and development method (MIPDD) had been developed for a design work of multifunctional jackets with optoelectronic technologies. This method has five working steps, including opportunity definition, opportunity exploration, opportunity confirmation, opportunity realization and achievement valuation. In the step of opportunity exploration, the method of personas was used and six items of key design themes were found out, which were practicality, aesthetics, portability, washability, multifunction and composability. Additionally, in the step of opportunity confirmation, the Delphi method was used, and the final average score of each key design themes were larger than 4.2 in a 5 points Likert-scale, which confirmed the significant importance of these factors.

This study is based on the abovementioned key design themes, and to design, fabricate and evaluate an innovative and multifunctional jacket integrating with optoelectronic components. The design method and results obtained from this study can help textile designers to develop their own optoelectronic apparel products.

Evaluation and Analysis Method

After completion of fabricating an innovative jacket, the method of questionnaires was used for user's evaluation of this prototype product. The samples joined in this survey were selected from college students of Taichung city in central Taiwan. Before completing the questionnaire, each attendee had read a document about traditional and innovative jackets with optoelectronic function, as well as had tried out these products. Therefore, all of the attendees could deeply understand these products, and were able to think about their own perceptions and opinions, i.e. they would have the capability to evaluate superiority, practicality and acceptance of the multifunctional jacket.

The contents of questionnaires were divided into three parts. The first part was basic information, the second part was the degree of identification about key design themes, and the third part was to grade the traditional and the innovative optoelectronic jacket separately according to items of key design themes.

The SPSS software package was used for data analysis and graphic treatment. The descriptive statistical analysis method was utilized to calculate frequency distribution of sample's basic information, such as gender, age, department, birthplace, etc. The Cronbach's alpha method was applied for checking the reliability of this survey, and the simple and the paired-samples t-test s were selected for handling the data of part 2 and part 3 in the questionnaires separately.

Design and Fabrication of Multifunctional Jacket

According to the key design themes which generated by the personas method and verified by the Delphi method from the previous study [8], this study had developed a series of design concepts as shown in Table 1. In terms of multifunction, a solar power system integrated with lithium battery was integrated to charge personal electronic devices, such as mobile phone and digital camera, and the functions of LED lighting and electric heating could also be introduced. For the aspect of composability, a flexible power control system for a variety of components could be used, and the components of solar cell, LED, heating element and battery could also be selected and composed depending on the condition of requirement.

The design of an innovative jacket with optoelectronic components was based on an electric heating jacket, which was revealed in 2013 by Fabric King Textile Co. [9]. To display the functions of optoelectronic effects, a solar cell and two LED yarns were added, as well as a battery and an electrical control device was also installed.

The electric system and component arrangement can be shown in Fig. 1. Both solar cell and utility power can supply electric energy to the system, and the system can provide electric energy to loads, which are LED lighting, electric heating pads and consumer electric products. The battery can store electric energy, and the power control device can manage electricity input, storage and output, as well as adjust electric voltage and protect the electric circuit and components.

The solar cell is obtained from Hemvan International Co. [10]. As shown in Fig. 2(a), the size of solar cell is 27×18 mm, the weight is 56g，and the power is about 1.5W. Two LED yarns are used for lighting and provided by Fabric King Textile Co. [9]. As shown in Fig. 2(b), the length of LED yarns is about 1 m, and the colors are white and blue separately. Three electric heaters are utilized and provided by KLC Corp. [11]. As shown in Fig. 2 (c), the dimension of electric heater is 3×3 cm，and total power requirement is about 0.9 W for maintaining the temperature at 45ºC. As shown in Fig. 2(d), a battery and a power control device are provided by Tropical Solar photovoltaic Co. [12]. The power control device has a connection port using USB connector for power output.

The innovative jacket fabricated by this study is shown in Fig. 3. The solar panel is installed on the center of backside of the jacket, so more likely to get adequate sunlight. A bag-type fixed set of solar panel is applied for easy detachment and washing. Two LED yarns are stitched along the right and left sides of backside of the jacket, and they can be turned on to emit light at night for increasing visibility and safety. There are three electric heaters. All heaters are sewn on the interior part of jacket, and one

is located under the collar of the backside of jacket, as well as the other two are located inside the right and left front pockets separately. Because the LED and flexible electric heaters are waterproof, they can be direct washing.

Table 1 The corresponding design concepts developed for key design themes

Key Design Theme	Corresponding Design Concepts and Solutions
Practicality	■ Use a versatile design and optional components ■ Increase the capacity of lithium battery to avoid power shortage in cases of cloudy day or indoor use
Aesthetics	■ Refer to the latest fashion trend ■ Offer a variety of fabric colors for choice ■ Provide flexible thin film-type solar cells for selection
Portability	■ Choose more compact optoelectronic components ■ Adopt a combinatorial design for user to select optoelectronic components
Washability	■ Detachable design for washing intolerance components ■ Utilize washable types of LED and solar cells ■ Add protection kits for corrosive electric connectors
Multifunction	■ Integrate solar power system with lithium battery ■ Provide charging function for consumer electronic products ■ Provide functions of lighting and heating
Composability	■ Use a flexible power control system for a variety of components ■ Select and compose the components of solar cell, LED, heating element and battery depending on requirement

The leads of these components are fixed between the fabric and the lining of jacket, and extended downwardly until the bottom side of the jacket to form a combinatorial wire string. Then this string detours to the backside of front left pocket, and finally passes through and connects to the power control device. The power control device and the battery are also put into the front left pocket, thus can connect with solar panel, LED yarns and electric heaters, and the battery can supply electricity if necessary. The power control device and the battery can be removed when the jacket is going to be washed. During the washing process, the connecters will be corroded, and a plastic protection cover should be put on before washing.

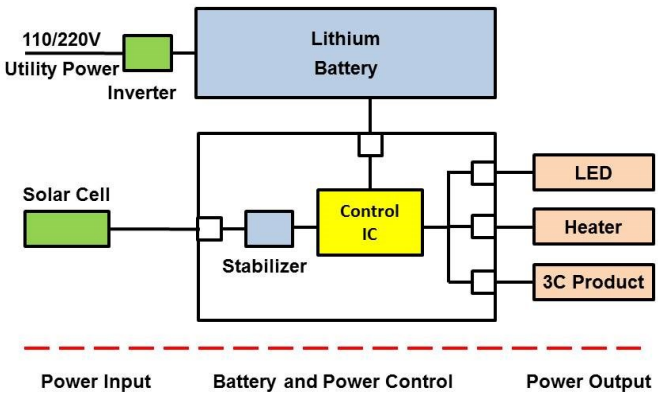
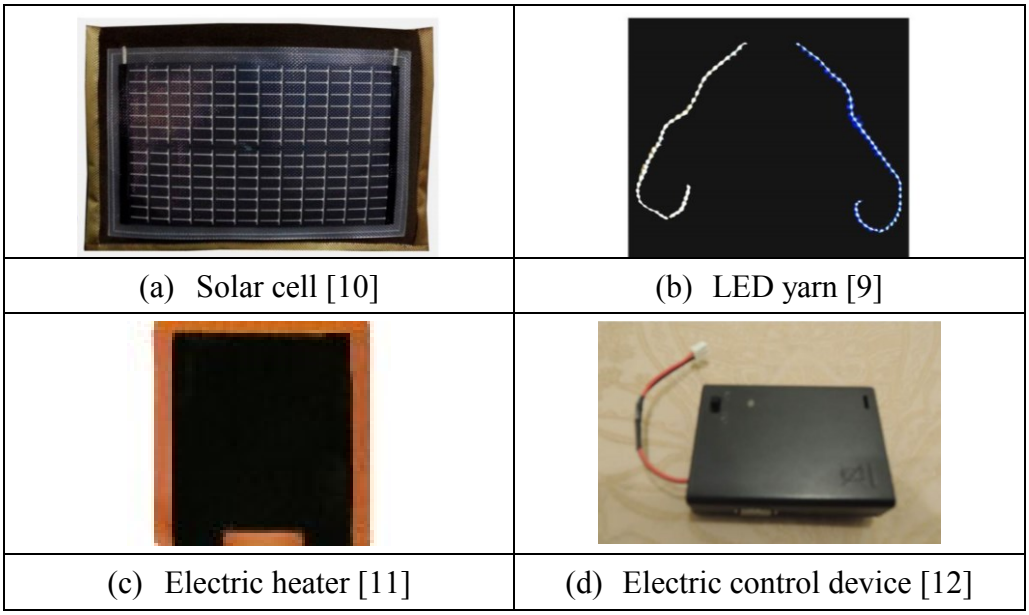


Fig. 1 Battery and electric control system



(a) Solar cell [10] (b) LED yarn [9]

(c) Electric heater [11] (d) Electric control device [12]

Fig. 2 Components used for the multifunctional jacket

In the case of flexible solar panel used by this study, the solar power is about 1.5 W under the condition of normal outdoor sunlight of clear day, and down to 0.5 W in cloudy day. Therefore, the solar panel can provide about 3 Wh during 4 hours of solar radiation in a sunny day. This electric energy is obviously not enough for fully charging a current smart cellphone, but it can provide some electricity to extend the utilization time of cellphone.

As for the application times of optoelectronic components used by this study depends on the capacity of battery. A lithium battery with 3.7 V and 5,200 mAh is selected to be used by this study. In the case of three electric heaters, the effective application time is 5.5 hours. In the case of two LED yarns, it will maintain 15 hours for the state of full brightness and 30 hours for the state of flashing. In the case of charging an iPhone 4S, the power requirement is 3.7V and 1,420 mAh, therefore the battery can provide enough electric energy to fully charge of this cellphone.

Fig. 3 A multifunctional jacket with optoelectronic components: front and back sides

Evaluation and Analysis of the Design Achievement

In this study, a survey of questionnaire was used to evaluate the prototype product developed by the MIPDD method. There were 300 copies of questionnaires had been sent out, and 242 copies were recovered with a response rate of 80.7%. After deducting the incomplete questionnaires, the copies of valid questionnaires were 214 with an availability ratio of 88.4%.

There are three parts of questions in the questionnaires, the first one is about basic information of participants, the second one is evaluation of importance of key design themes, and the third one is evaluation of traditional and innovative textile design with optoelectronic effect. The Cronbach's α values of these three groups are all greater than 7, i.e. the survey results meet the standard of internal consistency.

According to the consequence of the second part, the most important key design factor is aesthetics with an average score of 4.16, the second one is practicality with a score of 4.12, as well as the others are composability, practicality and portability sequentially. As shown in Table 2, the results are divergent for different genders. The males prefer practicality (4.37), multifunction (4.36) and composability (4.15), as well as the females favor aesthetics (4.48), practicality (4.01) and multifunction (3.94).

On the basis of t-test results, all of t values of the key design themes are positive, and p values are all less than 0.05. Therefore, the key design themes, including practicality, aesthetics, portability, washability, multifunction, and composability, display the positive effect for the decision making to purchase textiles with optoelectronic function.

As shown in Table 3, the scores of practicality, aesthetics, multifunction and composability of the innovative jacket with optoelectronic function are 4.21, 4.12, 4.07 and 4.84 separately, which are all higher than those of the traditional jacket, such as 3.66, 3.16, 3.47 1nd 3.32. However, the differences of scores in portability and washability are limited. To sum up, the average score of innovative textile is 3.87, which is significantly higher than 3.40 of traditional textile.

Table 2. The survey results of factors affecting decision making

Sequence	Which factor is important for decision making when you want to buy a textile with optoelectronic function?	Male	Female
1	Aesthetics	3.92	4.48
2	Practicality	4.37	4.01
3	Multifunction	4.36	3.94
4	Composability	4.15	3.79
5	Portability	3.30	3.87
6	Washability	3.92	4.48

The paired-samples t-test method is used for inspecting the discrepancy of evaluation results of the traditional and innovative textile with optoelectronic effect. The p values of practicality, aesthetics, multifunction and composability are all smaller than 0.05, i.e. these consequences have reached the inspection criterion of significant difference. However, the p values of portability and washability are 0.161 and 0.243 separately, which are greater than 0.05 and do not have the significant difference. For the overall analysis of six design themes, the p value is 0.018, which is smaller than 0.05 and has significant difference.

Concluding Remarks

A design strategy and solution had been developed depending upon the key design themes which were created by the MIPDD method, and an innovative jacket with optoelectronic function was designed and fabricated.

A survey method of questionnaires was completed to evaluate the design achievement. The paired-samples t-test method was used for inspecting the discrepancy of evaluation results of traditional and innovative textiles with optoelectronic effect. According to analysis results, the innovative jacket with optoelectronic effect developed by this study is better than the traditional jacket.

Table 3. The evaluation results of traditional and innovative jacket with optoelectronic effect

Item	The evaluation of different textiles depending on the following factors	Traditional Jacket	Innovative Jacket
1	Practicality	3.66	4.21
2	Aesthetics	3.16	4.12
3	Portability	3.38	3.48
4	Washability	3.41	3.49
5	Multifunction	3.47	4.07
6	Composability	3.32	3.84
Average		3.40	3.87

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