Developing Designs and Making Men’s Outdoor Breathable Waterproof Jackets with Solar Cells for Emergency Communications

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Abstract

This study provides the structural design for commercialization of outdoor breathable waterproof jackets for men merged with solar cells to enable emergency communications, utilizing wearable devices to develop smart clothing and extend convenience in everyday life. The most popular waterproof jacket with two-layer and three-layer moisture-permeable waterproof fabric was selected, based on previous studies of functional outdoor jackets and style with affinity to fashion. Flexible solar films suitable for clothing were embedded in the lining of the sleeve area and hood visor, and printed film was developed to balance weight and design. High performance smart solar jackets have application to expanding the use of smart phones for everyday and emergency communication, and leisure and outdoor sports activities, as well as day-to-day functions as a waterproof breathable outdoor jacket for men. It is also eco-friendly. Satisfying both the aesthetic and practical, a solar cell jacket with smart features, is an innovative tool for use in a variety of outdoor activities, and a fashion-forward commercialized product.

Key words : breathable waterproof, design prototype, emergency communications, outdoor wear, solar jacket

I. Introduction

The latest growth of the domestic market for performance outdoor apparel has been remarkable enough to reach over three trillion won in 2010, marking the third place in the world next to those of the United States and Germany ("high-flying outdoor", 2012), which continued to
record over 30% growth rate compared to the previous year in 2011 as well in spite of the economic slump and abnormal weather conditions together with the popularity of multipurpose outdoor jackets worn in daily lives not only in mountains (economic downturn, 2011). In the background of such a trend are several factors such as the improvement in the standard of living, the introduction of five-day week, and the increase of young urban consumers who enjoy diverse leisure sports with the concern of well-being. These factors seem to have been acting as catalysts that fueled the inflating demand of outdoor wear both functional and fashionable to be worn in daily urban lives as well as outdoor or sports activities (Jungmin Bae, 2011). The current urban lifestyle has been strongly affecting in shaping domestic outdoor-wear market to favorably tend to reflect the need of stylish quality urban wears with multi-purposed functionality. Thus, it is highly expected that the trend that functional outdoor wears coupled with the concept of urban casualism are strongly pursued will steadily be noticed in the outdoor wears market since consumers strive for highly functional products and at the same time they desire to be stylish (Kim & Ha, 2012).

Outdoor wear markets are rapidly expanding and the competition for the market share is getting more and more intense. Manufacturers are not just pursuing competitive pricing, but are trying hard to spread out their products (Jeong, 2011). As the market for sports wear keeps expanding, there’s an increasing demand for qualified functional materials, which helped manufacturers develop a variety of highly functional products with top-notch functional material optimized for specific sports activities to ensure wearers’ comfort. Thus, various kinds of multi-functional materials are being utilized in making outdoor wears ranging from permeable waterproofing, sweat-absorbing, quick-drying, antibiotic, deodorizing, radiating, UV-blocking to FIR (Far Infrared Rays) emitting (Sung, Jeon, & Park, 2005).

Unlike other general wears, outdoor wears are distinctive in that important factors affecting purchase decision lie in functionalities such as protecting body, keeping warm, water proof, wind proof, and so on (Jeon, Oh, & Kim, 2012). Permeable waterproof that is one of the most important functions in outdoor wear is that the fabric lets vapor pass through but keeps water out just like human skin does, which is also called ‘breathable’. Clothes made with this permeable waterproofing material can control the moisture inside the clothes to help wearers feel pleasant. Gore-tex by DuPont is a good example (Rhee & Lee, 2011). Developing new materials and designs is highly needed to satisfy consumers who want clothes good enough for their various outdoor activities such as bicycling, journeying, running, hiking, or camping. Manufacturers are eager to develop products that are aimed to the specific needs (Han & Lee, 2011). Smart outdoor clothes featured with some technological merits like position tracking, luminous fabric or built-in illuminating device on top of such material-related functions as sweat-absorbing, water repellent, wind proof and light weight will make a good market (Baek & Lee, 2011).

The previous studies on outdoor wears have been typically done in line with sports wear, training suits, or trekking wears (Im, Seo, Park, & Kim, 2011). They are mainly focussed on the functional materials, designs with considerations about specific needs of individual sports, and consumers’ behaviour. Some of the latest
studies (Lee, 2010) are found to be interested in multi-purposed sports wear such as trekking suits also worn as town-wear. Also, there are other kinds of studies on developing functional clothes coupling with IT devices involving Heatex, which applied conductive polymers to fabrics for the first time in the world, life jackets with LED system, and smart clothes plugged with devices like iphones to be controlled easily. In this atmosphere, it seems to be desirable to develop jackets using solar cells (Cha, 2004).

Outdoor wears have been evolving from protecting human body from natural environment to helping people enjoy various additional benefits. Therefore, manufacturers should turn to products equipped with highly functional features and setting up proper marketing strategy enough to satisfy consumers’ needs is more important than anything (Je, 2012). Besides, it shouldn’t be overlooked that ecological responsibility is also issued in the fashion world pursuing ‘green design’, ‘eco-green design’, or ‘recycling design’, etc. Ecological design is a concept that a designer not only acknowledges ecological, social, and ethical matters in fashion designing, but also considers overall effects that products can bring about in our society(Jiyoung Bae, 2008).

Now, let’s take a look at some overseas examples of R&Ds trying to use solar cells in fashion designing. Tempex developed Solar-Warm jacket that uses solar energy in keeping warm; Mustang Jeans, Bogner Solar-Jacket connecting USB port to flexible solar cells; KANZ, children’s solar jackets using solar cells and LED; Maier Sport, solar jackets equipped with flexible solar cells connected to GPS, a cell phone, an MP3 player, and some USB outlets. Also, Zegna Sports has introduced an interesting outer solar jacket for skiing that has detachable hard solar cells on the parts of neck and upper arms, which are connected to conductive fiber cables and batteries. The size of the rectangular solar module is 9 cm × 5.5 cm enough to produce 1W of electricity. Indarna DTX, an Argentine company that makes intelligent clothes, has recently developed a solar jacket that is equipped with detachable solar panels on the back sized 14.3 cm × 21.2 cm. It has a touch-pad button as well as the traditional functions such as permeability, water proof, and keeping warm. Solar vests made in China are also using detachable solar cells placed on the back connected to other panels and the battery. The battery is somewhat too big compared to other similar products even if it’s quite powerful. Likewise, we can find a number of studies and products to which solar energy by the use of solar cells is applied. However, such attempts and endeavors still leave rooms for improvement in that most of solar cells are using hard cells, which means they tend to be heavy and hard to feel and might easily be damaged when dropped causing malfunctioning. Besides, in order to increase capacity, more and more cells are being used, so that it has a negative effect on the appearance of the apparel and the bulkiness may well hamper free movement.

This study is an attempt to suggest a prototype of outdoor solar jackets for emergency communication that are both comfortable to wear and convenient to use facilitating communication in many kinds of urgent and dangerous outdoor situations. Batteries have been reduced to the minimum amount since it shouldn’t require a large amount of electricity to run an emergency communication system, which helped the jacket not to be heavy. Flexible cells are adopted instead of hard ones to give
jackets a better fit and to eliminate potential danger of being damaged. The prototype jacket is designed to work as a normal daily wear, a regular outdoor wear, and an extreme outdoor wear that is good for extreme weather conditions with special features involving permeable waterproof, emergency communication and is ecologically designed as well.

II. Methods and Procedures

1. Selecting Design and Plan

This is how we narrowed down and finalize the designs of the test jackets. First, 12 most popular brand jackets were selected from Yim Minjung (Im, Seo, Park, & Kim, 2011). The Study on the Prototype Designs of Men’s Functional Trekking Wears, and then on the basis of the 12 jackets, 4 outdoor brand designers analyzed outdoor brand catalogues in the last 3 years before they can decide the specific designs of the 3 parts of the test jackets: hood, body, sleeves to be the latest fads in order to finally determine the test jacket designs.

1) Hood Design

The hoods is designed as combined type not as detachable type since putting on and off may be a hassle, and added are a string and cord-locks for convenient size control when the wearer puts on a safety helmet for outdoor activities.

2) Body Design

Back side is designed longer than Front not to expose a part of body when the wearer bends down as well as to block wind, rain or snow. The length of the Back reaches around the middle of hips. A string or a chord is inserted in the hem to facilitate controlling the size. This string type of hem is more helpful than solid or elasticated hem in changing shapes and keeping warm as well. So, it’s a design considering both comfortability and keeping warm. The style of Body part is designed as a slim style which is a current fad, and draping is adopted for a better movement.

3) Sleeve Design

The sleeves are designed as draped raglan sleeves with a slit line. 4DM (4 dimension motion cut-out), which helps prevent pull-up, is adopted as lots of brands are normally using. It is known to ensure comfortable movements of arms and upper body. Waterproof function is also included. The shoulder protectors are welded on the shoulders to minimize friction from straps of a knapsack. The end of the sleeves are fastened with velcro as most of men prefer.

4) Zipper and Pocket Design

Light-weight waterproof zippers are used as most people prefer. The zippers used are listed as one at the front fastening, another on the opening of the pocket at around breast, two on the opening of the pockets near waist, and another two on the opening of the ventilations near armpit. The ventilations are effective for letting out heat and sweat during and after severe workout. These are adopted since those who frequently enjoy hiking preferred upper pockets and ventilations. The zipper for front fastening goes without cover plus waterproof
function since those who own many trekking jackets (over 3 jackets) don’t like covered zippers instead prefer light weight ones (See Figure 1). Shoulder Protectors (Figure 2) are welded on the shoulders in coated silicon fabric which effectively endures friction with straps of a knapsack. Inner chest pocket is shown in Figure 3.

2. Making Test Jackets

A three-ply bonded with mesh lining fabric for waterproof jacket, 3L is used for extreme cold as the least volume and 2L which is for four season or general purpose needs separate lining for protecting laminating. Therefore, even the same design, because the structure of the inner lining and specifications may vary in 3L and 2L, two fabrics are all selected for test jackets.

Two jackets are developed in the same design. One is in 3L outer material without lining, and the other is in 2L outer material with lining. With 3L or 2L as outer material, if seams are sealed, a total waterproof is possible. Also, sewing and seams are minimally reduced to help make jackets light-weight. Seam sealing tape is applied along the sewing line on the lining, which keeps rain water from coming through needle holes. Using seam sealing tape, seam ease can be minimized, which contributes to light-weight of the jacket. With 2L material, polyester lining is mainly applied and also mesh lining is partially used at the lower part of the waist to better drive out sweat. Draping for professional waterproof jackets is adopted which is also used by major domestic outdoor brands. The size of the jacket is decided to be L size, which is that of the average Korean man.

3. Designing Solar Panel Jacket

Flexible solar cells are built in the jacket that can charge mobile phones for about 30 minutes to enable them to be used for about 20 minutes. This feature is a great solution for
dead battery problem during outdoor activities such as hiking, mountaineering and camping. The solar cells can produce enough electricity to make emergency calls. Besides, it is definitely an eco-friendly way of getting electricity. The batteries used in the waterproof jackets are thin and flexible solar cells made by P-company. Installing the batteries and cables was helped by some experts who modified the batteries a little to best fit the jacket. The weight and bulk was minimally reduced to ensure good comfortability and not to hinder movements.

The solar cells were decided to be positioned at upper arms and the visor of hood that are always exposed with the hood on or off. Front and Back sides are excluded as they are significant parts in appearance. If solar cells were situated there, it would harm overall appearance since solar designs are quite conspicuous (See Figure 4). Three sheets of solar cells MDT6–75 are installed: two on the visor of the hood, and one on the left upper arm. Transparent plastic windows are devised for the solar cells to be inserted.

The capacity of the solar cells are about 1.08W (3.36V). (See Figure 5) The solar cell modules are connected to the battery pack, which stores electricity that the solar cells produce. Inside the battery pack are PCM (Protecting Circuit Module) and CVR (Constant Voltage Regulator), which prevent countercurrent, overload or over-discharge of the lithium-ion battery. CVR converts irregular DC (direct current) caused by uneven amount of sunlight into regular constant current before being sent to the battery.
4. Developing Solar Cells and Evaluation

Solar cells are not fabric but electronic gadgets, which means it’s not totally free to choose from or design them as much as needed. We cannot develop solar cells to be exactly fit to each clothes’ design and color. Thus, in order to compensate such problems, solar cells can be redecorated in the ways that do not hinder the performance of the cells.

In this study, a special printing on the solar cells is adopted. Checker and stripes patterns are decided to go well with popular shirts or jackets. The printing was selected not to affect the performance of the solar cells in any way. Experiment with a Solar Simulator (Figure 6) was carried on to find out any difference of performance among the kinds of designs. The experiment was done under the Standard Test Condition: Irradiance 1000w/㎡, Spectrum 1.5 Air Mass, Temperature 25°C. The selected solar cell is made of polymer at the back, which is light when made into a module and can be designed in a curved shape. Even if the module gets damaged or cracked, except the damaged part the rest of the module works normally to generate electricity. The material is quite durable and applicable to various kinds of materials including fabric. The printing designs are applied according to the colors (See Table 1).

III. The Results and Evaluations

1. The Characteristics of Solar Jacket Design

Based on a popular permeable waterproof jacket selected out of the best-sellers of the latest outdoor brands, waterproofing system is guaranteed by using waterproof zippers, and emergency smart phone charging system through solar cells is included.

2. Developing Waterproof Jacket Equipped with Solar Cells

Flexible solar cells are inserted in the transparent plastic windows welded underneath

![Nisshinbo Solar sun simulator 1222i-S Specifications](image)

**Figure 6. Nisshinbo Solar Sun Simulator 1222i-S Specifications**

<table>
<thead>
<tr>
<th>sample</th>
<th>color and pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>solar cell</td>
<td>original solar cell</td>
</tr>
<tr>
<td>stripe</td>
<td>white</td>
</tr>
<tr>
<td>checker</td>
<td>yellow C</td>
</tr>
</tbody>
</table>

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Table 1. Sample Design Applied to the Solar Cells
the visor of hood and on the left upper sleeve to generate electricity from sunlight. Inside the garment, double pockets are designed for carrying a cell-phone and for rendering passage of wires connecting solar cells and batteries.

1) Outer and Inner Material

A men’s permeable waterproof jacket pattern is developed. (See Figure 7, 8) Jacket A using 3L for outer material is seam sealed after sewing. Solar cells are installed and where there’s cables running is covered and stuck with velcro tape for the cables not to be seen. Developing the design for installing solar panels in Jacket A without lining is shown as Figure 9. The design of Jacket B using 2L as outer material with lining is shown at Figure 10. In Jacket B using 2L, there is a passage for cables and pockets to hold solar cell modules. At the lower part of the jacket, mesh lining is partly used to expel sweat quickly while exercising and to keep free of vapor. Table 2 shows material properties of outer shell 2L and 3L.

<table>
<thead>
<tr>
<th>outer fabric</th>
<th>2L</th>
<th>3L</th>
</tr>
</thead>
<tbody>
<tr>
<td>material</td>
<td>100% Nylon</td>
<td>100% Nylon</td>
</tr>
<tr>
<td>count(denier)</td>
<td>65</td>
<td>69</td>
</tr>
<tr>
<td>tensile strength(kg)</td>
<td>70.0</td>
<td>82.5</td>
</tr>
<tr>
<td>weight(g/m²)</td>
<td>120.2</td>
<td>135.5</td>
</tr>
<tr>
<td>vapor permeability(g/m²/day)</td>
<td>15531</td>
<td>13274</td>
</tr>
<tr>
<td>water pressure(cm²Pa)</td>
<td>1349</td>
<td>1588</td>
</tr>
</tbody>
</table>

Figure 7.
Outer Shell Pattern: Jacket A and B

Figure 8.
Outer 3L Shell Patterns: Jacket A

Figure 9.
Outer 3L Shell Jacket A Internal Specifications

Figure 10.
2L Jacket B-lining Internal Specifications
2) Detailed Design of Waterproof Jacket and Installing Solar Panels

A string tunnel is rendered at the back of the hood and the string is covered by a flying bird decoration which is stabled by a velcro, which facilitates controlling the size of hood according to individual head. The front of the hood is fastened by the string and chord-lock, and there’s a pocket at the visor of the hood to hold solar cells. Wires are also inserted in the front tip of the visor to help keep the shape of the hood from probable messing up caused by installing solar cells. On the surface, a transparent film is welded for solar cells to easily catch sunlight. Once solar cells are installed, velcro tapes are used to fasten them (See Figure 11, 12).

For the sleeve part, two ways of installing solar cells are developed. One is when a transparent film window is welded outside and a pocket is rendered inside for solar cells to be inserted from inside. The other is inserting solar cells from outside through zippers. If you don’t have to remove solar cells frequently, the way you insert the solar cell from inside pocket will be a better idea since it looks neat. However, if you need to take out solar cells from time to time, it would be far more convenient to use zippers from outside (See Figure 13). Figure 14, 15 shows solar built system with hood and sleeve solar battery pocket and cable passage in jacket A. Functional details applied to breathable jacket like back hood, front drawstring, pockets (chest and waist), ventilation, hood visor, welding protector and hem strings in Table 3. Table 4 shows specification of jacket A, B.
Table 3. Functional Details Applied to Breathable Jacket

<table>
<thead>
<tr>
<th>Details</th>
<th>Back hood</th>
<th>Front drawstring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Back hood, string</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chest pocket</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waist pocket</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ventilation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Battery pocket</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hood visor film</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solar cell insertion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protector welding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plastic + velcro</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hem string</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 14. Solar Built System
- Pocket and, Cable Passage

Figure 15. Cable Passage, Hood and Sleeve
Solar Battery Pocket of Jacket A
3. Developing Color Designs for Solar Cells to go with Jackets

Developing solar cell designs is carried on in an attempt to harmonize solar cells and the jacket. Altogether 9 designs in two kinds of patterns: checker and stripes in different colors were tested under a solar simulator. The results showed that checker pattern is not proper for solar cells to efficiently work while stripes pattern is not affecting solar cells in any negative way. Decorating solar cells with printing patterns looked more stylish (See Figure 16). The white part of the solar cell is found no hindrance to work when painted, so this is where you can paint whatever color you may wish. Checker pattern is found to greatly deteriorate capacity up to 1/5 of regular amount of generation, so it must be avoided. Checker patterns show Pmax 0.39~0.79, which is 16~32% of natural solar cell Pmax (2.47) and it is not suitable for solar cell print design. On the other hand, stripe patterns show Pmax 1.75~1.83 of 74~80% of solar cell Pmax and it is available for solar cell print, although even decrease 20% energy efficiency (See Table 5). In case checker pattern is faded down or greatly lowered down in color density, the negative influence subsides. Stripes pattern accounts for 80% of all patterns. So red stripe pattern is selected for solar cell design to be matched with Jacket A in navy color. Based on the results of the test, the most suitable patterns of solar cell are adopted for Jacket A and Jacket B (See Figure 17). With this, not only outdoor jackets but also other daily accessories like bags can be applied with solar cells to add smart functionality and satisty fashionability as well. As a result, solar cells can be used to go with diverse colors of jackets or to serve as a decorative item.

Therefore, this study is intended to introduce a prototype of a practical jacket that can be used right now. The jacket adopts the latest fad, permeable waterproof functionality, plus solar cell technology. Replacing conventional hard solar cells with flexible cells, it greatly enhanced comfortability and solved major problems due to hard cells. The hard cells were not comfortable
### Table 5. Design Applied Solar Cells Test Results

<table>
<thead>
<tr>
<th>Samples</th>
<th>( P_{\text{max}} ) (Rated output)</th>
<th>( I_{\text{sc}} ) (Short-circuit current)</th>
<th>( V_{\text{oc}} ) (Open circuit voltage)</th>
<th>( V_{\text{pm}} ) (Maximum output voltage)</th>
<th>( I_{\text{pm}} ) (Maximum output current)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar cell</td>
<td>2.47639</td>
<td>0.17777</td>
<td>23.38471</td>
<td>17.55322</td>
<td>0.14108</td>
</tr>
<tr>
<td>White covering</td>
<td>2.04852</td>
<td>0.14434</td>
<td>23.15140</td>
<td>17.77090</td>
<td>0.11527</td>
</tr>
<tr>
<td>Blue stripe</td>
<td>1.83573</td>
<td>0.13130</td>
<td>22.98152</td>
<td>17.58409</td>
<td>0.10440</td>
</tr>
<tr>
<td>Red stripe</td>
<td>1.75315</td>
<td>0.12513</td>
<td>22.90367</td>
<td>17.66180</td>
<td>0.09926</td>
</tr>
<tr>
<td>Yellow stripe</td>
<td>1.83731</td>
<td>0.13116</td>
<td>22.95991</td>
<td>17.66175</td>
<td>0.10403</td>
</tr>
<tr>
<td>Yellow c.</td>
<td>0.79854</td>
<td>0.06457</td>
<td>22.26189</td>
<td>18.80611</td>
<td>0.04246</td>
</tr>
<tr>
<td>Green c.</td>
<td>0.39570</td>
<td>0.03730</td>
<td>21.63837</td>
<td>17.44844</td>
<td>0.02268</td>
</tr>
<tr>
<td>S.blue c.</td>
<td>0.96672</td>
<td>0.07358</td>
<td>22.45366</td>
<td>18.58547</td>
<td>0.05201</td>
</tr>
<tr>
<td>Multi c.</td>
<td>0.79251</td>
<td>0.07768</td>
<td>22.33888</td>
<td>16.59048</td>
<td>0.04777</td>
</tr>
</tbody>
</table>

**Figure 16.** Original Solar Cell and Design Applied Cells

**Figure 17.** Design Applied Solar Cell and Color Matching Waterproof Breathable Jacket

and fragile when dropped causing damage as well. The previous solar jackets hired a lot of solar cells covering front and back, so that it looked far from being stylish and could be used only for a special purpose. Large size of batteries caused problems concerning weight and comfortability, which was a good reason that consumers didn't welcome such jackets. In order to solve the problems, this study developed the emergency charge system during outdoor activities enabling 30 minutes of phone call, which is assumed the most necessary function. Furthermore, when the image of solar cell seems to be somewhat heavy and distant for normal people, the attempt to match the design of solar cells and fashion will contribute to enhance the marketability of the products.

### IV. Conclusion

Currently, regular outdoor wears are predominating the market as casual outdoor and city outdoor pursuing urban outdoor wear to be worn in daily lives as well. More and more diverse outdoor wears conjoined with IT technology, so called smart wearable IT products should be developed and will be admired.

To satisfy the needs of contemporary users...
who enjoy various kinds of leisure activities, proper functionality must be considered at the same time as well as fashionability in designing apparel. This study is mainly focussed on the development of wearable devices with convenience and comfortability for both outdoor life and urban life. In the specific attempt to do that, the study tried to suggest a prototype of practical men’s jacket that combines outdoor waterproof and solar system for emergency communication. The result are as follows:

On the basis of the previous studies on functional outdoor trekking jackets, the most preferable detailed parts are decided and two kinds of permeable waterproof jackets are made with 3L and 2L materials.

Flexible solar cells are applied using solar films and proper materials for flexible clothing. Three solar cells are attached at visor of hood and the upper arm. The capacity of the cells is 20 minutes phone call after being charged for 30 minutes.

Jacket A with 3L material used covering and velcro to unseen the cables and battery pocket. Jacket B with 2L used the same material as lining to make the covering and sewed the zipper pocket. Transparent film is welded outside the pocket holding solar cells and two ways of inserting cells are devised: inserting solar cell from inside the pocket or inserting solar cells from outside through zippers.

To harmonize the designs of the cells and the jacket, the idea of designing cells is experimented. The results showed that checker pattern in not effective while stripe pattern is preferable. The white part of the solar cell was found to be no problem with any kind or color of printings.

With all these, solar cells can be applied not only to jackets but to many other items like bags to satisfy our practical needs and artistic needs as well. This study is believed to serve as a useful stepping stone that can guide smart outdoor age where we can enjoy leisure activities not leaving our smart devices behind providing a way to ensure emergency communication, and hopefully serve as a catalyst to encourage many other practical products utilizing solar cells to be on the market.

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