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A Study on the Development of Sensor-Based Smart Wappen System -Focus on UV Sensor and Gas Sensor-

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Keywords

gas sensor, UV sensor, smart wear, wappen, user

Abstract

The objective of this study was to develop a wearable systems that protect users, based on sensors that are easy to use, from accidents caused by harmful gases in the operator's poor working environment or the risk of ultraviolet rays during outdoor activities. By developing smart wappen with Light Emitting Diode (LED) light alarm function including UV sensor and gas sensor and central processing unit, systems that are applied to daily wear and work clothes to explore the possibility of user-centered, harmful environment monitoring products in real time were proposed. Each sensor was applied to sportswear and work clothes and the wappen system consisted of lightweight and thin form as a whole. Wappen to cover the device had one sheet cover on the front and another cover from the inside to form a sandwich like formation. Wappen was made in the same form as regular clothes that doesn't damage the exterior then a removable wappen system was developed using Velcro and snap methods to enable the separation of device or the exchange of batteries. De-adhesion method can occur in two ways, from the outside and from the inside, so the design is selected depending on the application. This study shows the significance of the development of sensor-based smart clothing, in that it presented a universal model for users.

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I. Introduction

Recently, as Korea reached the age of 100, there has been a growing interest in health and well-being. Also, with the increase in leisure activities due to the five-day workweek, people are participating in various outdoor activities. Therefore, sun exposure time due to outdoor sports movements is increasing. The use of sunscreen and clothing with sun protection became very important. In addition to the rapid industrialization process, the rash use of Freon gas and halon materials has destroyed the ozone layer in the atmosphere, increasing the amount of ultraviolet rays reaching the surface and increasing skin disorders. From the experts' point of view, Freeman estimates that if the ozone layer decreases by 50 percent, DNA damage will increase by 2.5 times and skin cancer rates other than melanoma will increase by 7.7 to 8.0, Kelflens demonstrated that excessive exposure to ultraviolet radiation is closely related to skin cancer, as increased by 1.56% and increased skin cancer other than melanoma by 2.7%, when the ozone layer decreases by one percent.(Gao, 2008)

Thus, the harm caused by ultraviolet radiation is increasing. The air pollution problem is also becoming serious due to the rapid industrialization of development and various factors such as manufacturing plants, coal-fired power plants, and automobiles. Therefore, for the sake of health, people who do outdoor sports activities or workers in poor workplaces. It is necessary to develop a simple user-centered monitoring system that can reduce damage caused by ultraviolet rays or harmful gases.

A wide range of smart wear is being developed based on wearables, we believe that users need a way to monitor risk information on their own and manage and respond in real time from these harmful environments.

This study is aimed at developing wearable systems that protect users themselves based on sensors that are easy to use for wearable users, to prevent accidents caused by harmful gases in the operator's poor working environment or the risk of ultraviolet rays during outdoor activities. By developing Smart wappen with Light Emitting Diode (LED) light alarm function including UV sensor and gas sensor and central processing unit, we propose systems that are applied to daily wear and work clothes to explore the possibility of user-centered, harmful environment monitoring products in real time.

II. Theoretical background

1. Damage and Prevention of Ultraviolet Exposure

The visible wave lengths of sunlight are called visible rays and it has wavelengths ranging from 400nm to 700nm from purple to red. Ultraviolet rays are called UV (Ultra Violet), which means light that has a shorter wavelength than the purple of visible light. We call it ultraviolet (UV) rays, which collectively refer to electromagnetic waves in the region of 10 to 400nm. According to the wavelength, it is divided into UV A, B, and C. The wavelength of 320 nm to 400 nm is called UVA (ultraviolet rays A, Long wave ultraviolet, near-infrared), waves range from 280 nm to 320 nm is called UVB (ultraviolet rays B, medium wave ultraviolet rays), and wavelength of 200 to 280 nm is called UVC (ultraviolet rays C, short wave ultraviolet)(Gao, 2008). Because 35 to 50 percent of UVA goes through clouds, fog, and windows and passes through the epidermis and reaches the skin and UV-radiation disorders accumulate and work on the skin in everyday life, ultraviolet rays of life is also a part of concern. Therefore, sunscreens should be used for daily and outdoor activities, or physically blocking UV rays that protect skin from sunlight with hats, scarves, sunglasses and clothing.

Also, the effects of UV rays on skin vary with wavelength. Ultraviolet waves are divided into UVA (320 - 400 nm), UVB (280 - 320 nm), and UVC (200 - 280 nm) and are not visible but respond differently to each wavelength(Chang, 1996). UVA destroys the components responsible for skin elasticity in the layers of the skin such as collagen and elastin fibers, causing optical aging such as wrinkles, freckles and pigmentation. UVA also penetrates the interior glass windows and into the skin layer, causing protein transformations in the layer (Mun et al., 2008). UVB acts as a sunburn and destroys cell genes to promote the freckles, makes free radicals in the human body and promotes aging(Park & Cho, 2015; (Seo, 2001). In addition, the increased amount of ultraviolet light caused by the depletion of the ozone layer has a large impact on the human body with excessive UV exposure, including sunburn, skin cancer, and pigmentation to those who are engaged in outdoor activities. With the diversification of leisure activities and increasing number of outdoor activities, various skin problems are being highlighted due to the increased time of leisure activities(Park & Cho, 2015).

According to the Association of Korean Dermatologists, 20 university hospitals nationwide have analyzed the number of patients with skin diseases caused by ultraviolet rays in the last 10 years. In young people in their 20s and 30s, black mushrooms and skin cancer increased by 1.4 times and 3.8 times, respectively. In particular, men need to control their skin and prevent ultraviolet rays, as their incidence of skin cancer has increased five times. Therefore, it is recommended to use sun block products for job groups that are exposed to ultraviolet light for over an hour every day(Park & Cho, 2015).

Also, most of the clothes we wear on a daily basis block UV rays to some extent, but the minimum UV protection index must be 15 or higher to provide adequate UV protection(Davis, Capjack, Kerr, & Fedosejevs, 1997; Sung & Jeon, 2005). Research on UV protection clothing so far shows the effects of UV protection according to textile components or processing methods(Choi, 2003), or UV protection of work clothes and physiologic examination of human body in terms of fiber science and textile physiology. And wearable devices like June which is a bracelet-type have UV sensors that allow you to check the ultraviolet level of where you are. Thus, in the age of convergence of the fourth industrial revolution, comfortable smart clothing, which helps users perform sun-blocking behaviors on their own through the detection and alarm functions of smart sensors, needs to be actively conducted.

2. A Study on Hazardous Gas Exposure

With the start of full-scale economic development since the 1960s, Korea has grown speedily with rapid industrialization. As a result, the air pollution problem is becoming serious due to the indiscriminate development and the various factors such as the manufacturing plant, coal-fired power plant, and automobiles. Air pollution has a significant effect on the human body, and it involves SO2(sulfur oxides) from the burning of fossil fuels mainly used in factories, power plants and homes, Carbon monoxide (CO, carbon monoxide), Hydrocarbon (HC), and nitrogen oxides (NOX, nitrogen oxide) arising from automobile exhaust(Son, 2009). In particular, the main cause of air pollution in the densely populated areas is CO and NOx as emissions from automobiles. These gases are known to have many negative effects on the human body(Kim, 1998; Yi & Kim, 2015). The "Regulations on Industrial Safety and Health Standards" define harmful gases as hazardous substances such as carbon dioxide and hydrogen sulfide in enclosed spaces occur in the air as gas. The accident of harmful gas leakage at these industrial sites is characterized by serious environmental pollution as well as many lives and property damage. Currently, most industrial companies that treat many compounds as raw materials such as the nation's chemical, petrochemical and semiconductor industries are preventing accidents only by conducting safety education for factory workers and conducting regular safety checks through safety officers until now. Executing safety precautions by field workers and performing their own internal audits can help prevent many accidents (Min & Kim, 2013), but it is absolutely impossible to prevent unpredictable accidents such as obsolescence and defects in process facilities or gas leaks due to natural disasters with this institutional system alone.

The currently developed USN-based hazardous gas monitoring systems have been developed mainly as operators-based monitoring systems and are insufficient to provide workers with hazardous environmental conditions in real time. Therefore, the need to develop monitoring of workers-centered hazardous environment is increasing(Nam, Lim, Lee, & Kim, 2016). In particular, if harmful gas detectors are convenient and easy for those working in a closed space, they can significantly reduce the occurrence of accidents and conveniently use the detectors for concentration of gas and dust in the environment, in the kitchen or in the laboratory. Traditional gas measuring instruments that measure the environment are expensive and difficult to use, but it is enough if simply have information to be recognized as be in a dangerous environment(Hong, Yoo, Jeong, & Yu, 2017). Therefore, a simple device is needed to facilitate use and recognize the risk information without special controls.

Studies on devices that are available to users include a study of hazardous gas wearable devices that can easily detect danger by lighting up red LEDs if there is a high level of gas or dust in the air or heart rate increase(Hong at al., 2017). But, it is about device development itself and research into the application of clothing is very poor until now.

This study is therefore meaningful in developing wearable wappen systems that are universally applicable to clothing for workers and ordinary people. Workers working in a closed space or ordinary people can easily recognize exposure to hazardous gas while working and try to ventilate or go out. It can also be used by ordinary people who are sensitive to harmful dust in the atmosphere when they go out.

Ⅲ. Research plan and process

1. Working Process Plan

After analyzing data received from UV and GAS sensors through MCU(Micro Controller Unit), each wappen was manufactured to apply to sports wear jacket and work clothes jacket so that LED light could output them. Power for LED drive and control is mounted on the battery and the operating process is shown in Figure 1.

2. Smart Wappen Device Hardwear Plan for Sports Jacket and Work Wear

The design of smart wappen device consists of uv sensor or gas sensor as input devices, and LEDs as output devices, cpu, and batteries for power supply. UV sensor(ML8511) detects 280-390nm light most effectively. This is categorized as part of the UVB (burning rays) spectrum and most of the UVA (tanning rays) spectrum(ML8511 UV sensor hookup guide, 2018). The gas sensor(CCS811) is a gas sensor solution that senses a wide range of Total Volatile Organic Compounds(TVOCs), including equivalent carbon dioxide (eCO2) and metal oxide (MOX) levels(Sparkfun air quality breakout-CCS811, 2018). The resources and roles for each module are shown in Table 1.

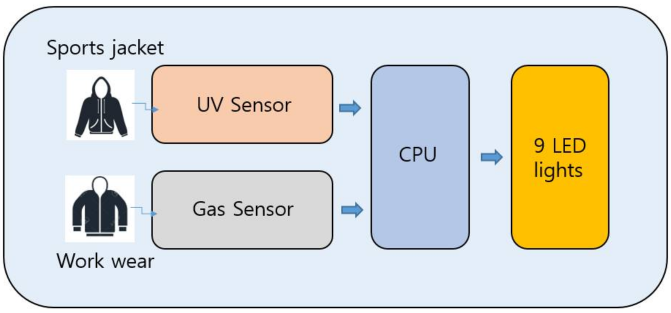
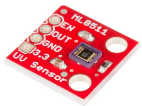
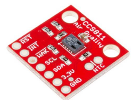
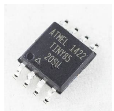


Figure 1. Operating Process for Sports Jacket and Work Wear Jacket

Table 1. Sensors, Battery, LEDs and CPU Specifications

	Sports Jacket	Work wear Jacket
Sensor module	ML8511: UV sensor  Ultraviolet light sensor. Analog signal	CCS811: Gas sensor  Air quality monitoring
Battery	CR2032: Coin, 20.0mm Lithium 3V Battery  Non-Rechargeable (Primary)	PD2032: Coin, 20.0mm Lithium 3.7V Battery  Rechargeable(Primary)
LED	Use to show signal  Size: 0805 (0.8mmx0.5mm) Color: White	Use to show signal  Size: 0805 (0.8mmx0.5mm) Color: White
CPU	Attiny85:  High-performance Operates between 2.7-5.5 volts.	ATMega328P:  High-performance Operates between 1.8-5.5 volts.

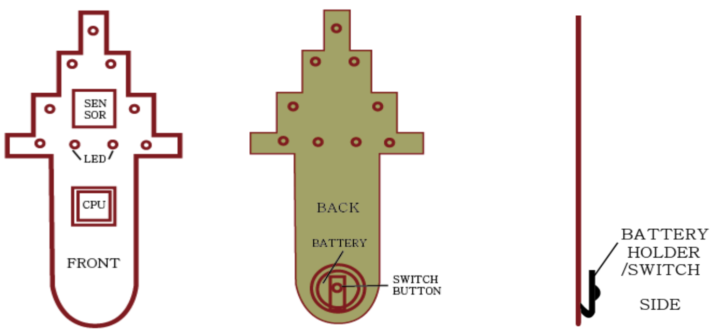


Figure 2. Smart Wappen Device Structure and System

3. Smart Device Structure

A thin, 1 to 2mm thick plastic substrate was used as the device to be fitted to the wappen. In the front, there are 9 LEDs and UV or gas sensors in the center that are sensitive to harmful environments that can be well recognized by users and their neighbors, and CPU. On the back side, the battery was mounted in a holder that holds the coin battery, and the LED was controlled by pressing the switch button on top of it. The structure of it is shown in Figure 2.

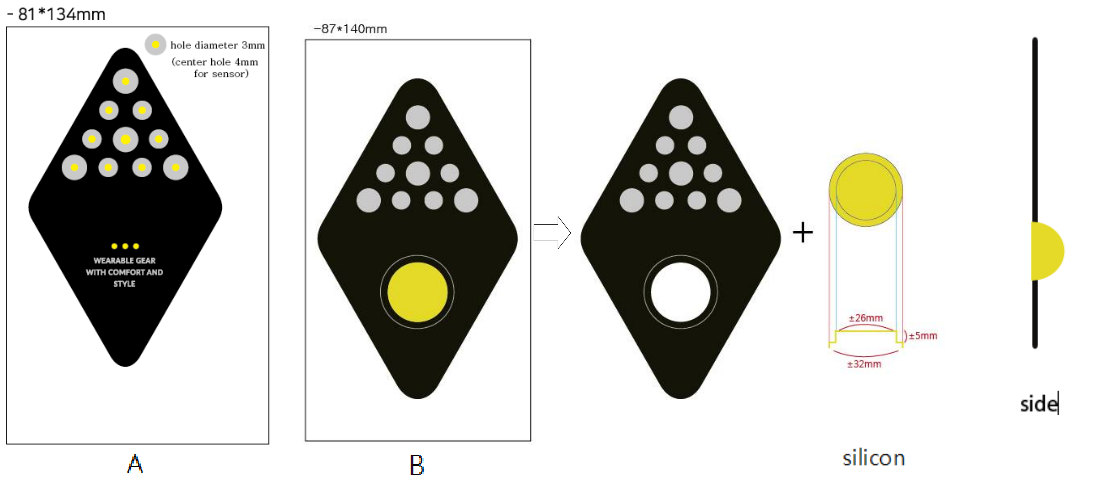


Figure 3. Outer Wappen(A), Inner Wappen(B) and Silicon Dome Construction of B

4. Wappen Structural Design

The design of wappens equipped with device which has ultraviolet sensor, gas sensor and nine highly cognitive LEDs is as follows. Smart wappen consists of two wappens, which are outer wappen(A) and inner wappen(B) which attaches to the inside of a jacket. The outer wappen consists of total 10 laser cutting holes(9 LED lights hole and a sensor hole), so the sensor can detect through it. A silicone round dome is provided at the bottom of a inner wappen so that LEDs can be turned on/off when pressed on it. The material of wappen was 1.5 mm thick synthetic leather and printed with PVC silver. The design for wappen systems are shown in Figure 3.

IV. Results and consideration

1. Wappen and Module System for Jackets

Sportswear with frequent UV exposure was chosen for wappen for UV sensor applications and for gas sensors, working clothes that could be exposed to harmful gas was chosen. A wappen position was set on the sleeve of each jacket. Jacket was laser cut 7mm smaller than the wappen size at the wappen position. We put Velcro which was cut with laser around the jacket hole. Velco material is 0.7mm thickness of slim Nylon Velcro fabric. And we sew the outer wappen(A), jacket, and Velcro at the same time. We attached the device backside of outer wappen from the inside of the jacket. The method of sewing wappen on jacket is shown in Figure 4.

Also, Laser-cut Velcro are sewn on the back edge of the inner wappen(B). We put inner wappen(B) on the inside of the jacket to cover the device. If necessary, it is easy to detach the device for battery replacement and laundry the jacket. Figure 5 shows the systems of two wappens and device together.

2. The Convenience of Structures Using Different Detach Systems of Wappen

Each UV sensor and gas sensor are used in the jacket of traditional sportswear and work clothes to apply wappen equipped with device, and finally intended to develop general purpose wappen systems. Existing developing wearable devices has many issues to consider, such as laundry convenience or heavy weight, excessive design changes, aspects of incompatibility with jacket designs and user convenience. To improve such problems,

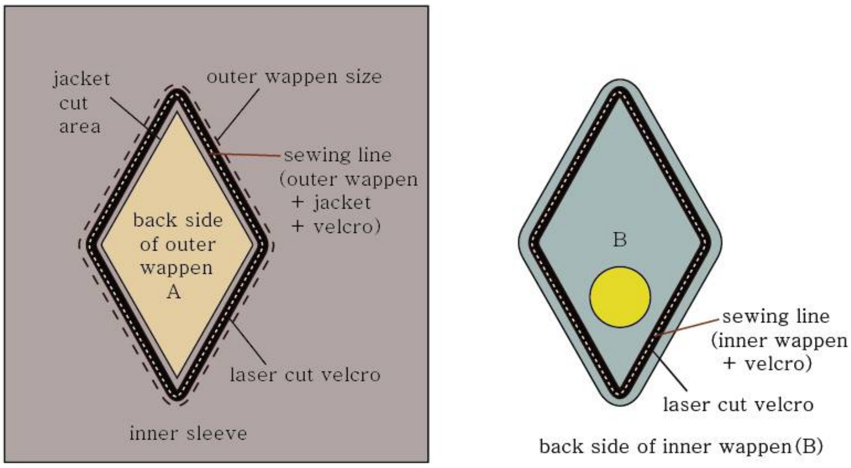


Figure 4. Sewing System of Outer Wappen(A) and Inner Wappen(B)

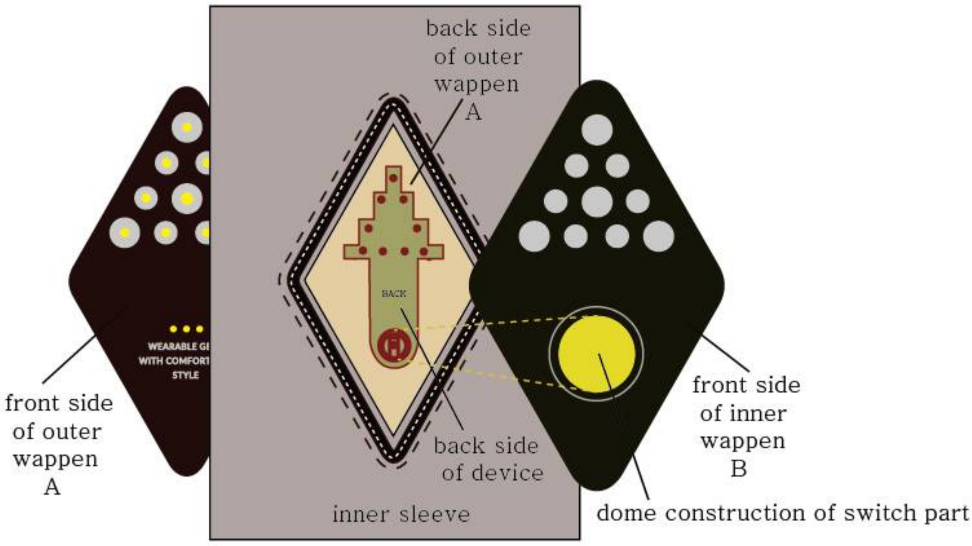


Figure 5. Design of a Device Attached to the Back of the Outer Wappen and Inner Wappen to Cover

applicable wearable wappen system was designed. The wappen structure of this study is composed of two layers of synthetic leather wappens, which are lightweight with two pieces covering the outer fabric and inner device, the device is also compact with a 1 mm thin plastic PCB(Printed Circuit Board) substrate and is designed to be generally light. And in the case of laundry, opening the Velcro of the inner wappen from the inside could immediately remove the device and replace the battery in the same way(Inside detach system). From the outside, the state of the sewing with the outer wappen and the jacket was designed to match the jacket design. In addition, the part of silicon dome could individually control the LED on/off when pressed inside and even outside, if necessary.

Secondly, if used in reverse use of outer and inner wappens and the dome construction came out to front, it is possible to change the battery from outside or also detach the device in the same way(Outside detach system). So, we also created a new device structure that fits for it. It is possible to change battery holder and switch from back to front of current device. In this case, the inner wappen is sewn with the backside jacket, and the device is attached to the backside of inner wappen in the front, and the outer wappen could be attached with velcro or gorgeous snaps. Thus, the application of wappen systems could proceed in two different designs, depending on its use, inside of the sleeve and outside in a removable way. The application of the wappens and the device is shown in Table 2 and Table 3.

3. Test Operation of the Sensor Jacket

To test the operation of the UV sensor, the UV sensor jacket was lit up from the UV wavelength LED lamp in the laboratory room and checked, and nine LEDs were lighted to confirm. It is shown in Figure 6. If we program with different colors or different LED lighting patterns depending on the intensity and time of the uv sensors, we will be able to design more diverse warnings. It was a limiting factor in this research, but it will be possible to try for next research. And for the gas jacket with gas sensor, we tried to check the gas lighter which has toxic butane close to it and saw it working well. The next study will be to change the design of LEDs pattern or give warning tones for each of these gases in specific states.

Table 2. Two Detach Systems of the Wappens

	Wappen systems	
Inside Detach System	how to detach the battery with Velcro of the inner wappen	backside of inner wappen with velcro / side
	  	 
Outside Detach System	outer wappen with snaps	device on the backside of inner wappen
		

Table 3. The Appearances of the Sensor Jackets

	UV Sensor JACKET	Gas Sensor JACKET
Jacket Wearing		
Wappen Sewing Appearances		

UV LED lamp
with 360-400 nm wavelength

Figure 6. Test Operation of the UV Sensor with UV Lght Lamp

V. Conclusion

With the recent increase in health care and the increasing number of people participating in outdoor sports activities, more convenient wearable products are needed for people from damage caused by ultraviolet rays from outdoor sports such as the Han River and leisure activities and for workers exposed to harmful gas in closed spaces of air pollution and industrial environment. Thus, this study developed a wearable system that can detect with UV sensor and gas sensor applying to jacket. For users, wearable based smart clothing should be applied to frequently worn clothing and should be convenient to use without being stuffy or uncomfortable, so the development of a general purpose wappen system applicable to any garment is of great importance. Most smart clothes developed today are heavy or poorly designed. we wanted to develop smart wappen by utilizing sensors, that is easy to operate, while being light and easy for ordinary people to recognize. Device to be mounted on a wappen includes a thin, 1mm plastic substrate, total 9 LEDs that the user and the surrounding people can recognize, UV or gas sensor and cpu that are sensitive to harmful environment. On the back side of it, the battery was mounted in a holder that holds the coin battery, and the LED was controlled by pressing the switch button on top of it.

Each sensor was applied to sportswear and work clothes and consisted of a lightweight, thin form of wappen as a whole. Wappens to cover the device had one sheet cover on the front and another cover from the inside in the form of a sandwich. Wappen was made in the same form of it as regular clothes that doesn't damage the exterior and a removable wappen system was developed using Velcro and snap methods to enable the separation of device or the exchange of battery. Detach method can be selected in two ways, from the outside and from the inside, so the design can be selected depending on the application. It is also believed that sensing of UV and gas with a certain intensity will provide strong lighting from nine highly recognizable LEDs, thus providing alarms to the wearer and surrounding workers and colleagues, thereby complementing areas that one might miss.

Although this study has been applied to the sleeve of the jacket, it is expected to be applicable in other locations depending on the use, such as chest or back, and can be meaningful in that various sensors can be applied to different garments for different purposes. Subsequent studies will provide the improved systems by programming LED lightings for different gas types in different patterns, adding more specific recognition and alarm systems. This study shows the significance of the study in the development of sensor-based smart clothing, in that it presented a universal model of wappens. It could help boost product development in wearable smart clothes.

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