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FLEXIBLE UVC WRAP FOR SANITIZATION OF CARRY-HOME ITEMS

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ABSTRACT

The COVID-19 pandemic has raised concerns on public health and household safety. Contamination of carry-home items by the SARS-CoV2 virus represents a potential risk to households. The common method of manual wipedown of carry-home items using liquid-form disinfectants is not a controlled and standardized process due to differences in operator performance and various surface types and topology. This project aims to develop a cost-effective and convenient UVC sanitization device that accommodates carry-home items of different surface topologies. The device is designed in the form of a flexible wrap and can be manually fabricated using readily available off-the-shelf components. Preliminary testing has shown that the device is capable of producing minimum UVC intensity of 27.17µW/cm² at 275nm wavelength which exceeds the minimum value of 19.97µW/cm² required to deactivate the coronavirus in 30 seconds.

Keywords:
COVID-19, UVC, Sanitization, Carry-home, Automated, Consumer Goods

NOMENCLATURE

COVID-19	Coronavirus disease caused by SARS-CoV2
LED	Light-emitting diode
UVC	Radiation within the ultraviolet spectrum which extends from 200 - 280 nm wavelength

1. INTRODUCTION

The COVID-19 pandemic has impacted a total of 215 countries thus far, with countries still hitting new record high on daily diagnosed cases following eight months after the pandemic declared. Among modes of transmission of the COVID-19 virus, the role of contaminated surfaces or objects leading to contact transmission must not be undermined [1].

For example, evaluation of viability of the SARS-CoV2 virus on stainless steel and plastic surfaces have shown an estimated half-life of 5.6 and 6.8 hours respectively [2]. This finding supports the possibility of introducing the SARS-CoV2 virus into one's home through contaminated food packaging, grocery bags, school/work backpacks and other carry-home items.

To eliminate the potential risk of virus transmission by carry-home items, a common method is to manually clean the item surfaces with cleaners or disinfectants [3]. However, given the various and complex surface topology, it is difficult to verify the effectiveness of manual cleaning due to variation in method, time taken and/or concentration cleaning agents used by the operators.

UVC radiation has been studied as an effective inactivator of viruses [4]. Based on its application, we developed a convenient and flexible UVC-emitting wrap device to sanitize carry-home items which are possibly contaminated with harmful pathogens at the surface level. The design of the device is intended to achieve the following: 1) standardize, semi-automate and increase the efficiency of the sanitizing process by simply wrapping the device over carry-home items of various geometries and surface topologies, 2) enable easy storage and transportation of the device, and 3) ability to operate the device without training.

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2. MATERIALS AND METHODS

2.1 Initial Prototype

The device assembly prototype consists of two components: UVC emission unit and reflective wrap. **Table 1** displays the information on material used in fabrication of prototype.

TABLE 1: Bill of Materials

Material	Source	Item Number
275 nm UVC LED	Multiple – see Table 2	Multiple – see Table 2
Stainless steel washer	Grainger	#12
¼-in Copper tape	N/A	N/A
Diamond film foil	Vivosun	B01MZ72PAH
Copper tapes	N/A	N/A
Silver epoxy adhesive	MG Chemicals	8331-14G 8331
Power adaptor (12V with relay switch)	SZYSK	8541760376

The UVC emission unit component was constructed by first applying two pieces of copper tapes on a washer to size. A single unit of UVC LED (nominal wavelength: 275nm, projection angle: 60°) was then bonded on the copper tapes by silver conductive epoxy at 140°C (**Fig. 1**). UVC LEDs from three different suppliers (all LEDs have the projection angle of 60º) were used in this study. The LEDs were selected based on off-shelf availability from the suppliers.

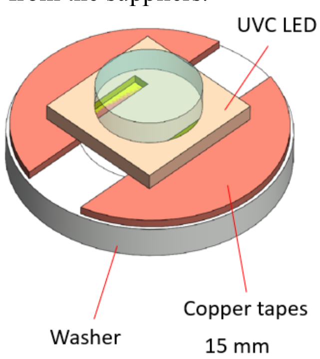

FIGURE 1: 3D image of UVC emission unit which consists of copper tapes, washer and UVC LED.

The reflective wrap was constructed using an 80cm x 80cm diamond film foil sheet as the base layer (single-side reflective). Copper tape of ¼-in width was then applied onto the non-reflective side of the wrap to route the circuit for powering the UVC emission units (**Fig. 2a**).

Four UVC emission units were then installed on the circuit through soldering using silver conductive epoxy, with the LED on the reflective side of the wrap (**Fig. 2b**). As final step, custom flexible PVC spacers were installed onto the reflective layer between each UVC unit (**Fig. 3**).

NOTE: This prototype size consisting of only 4 UVC emission units was selected for testing purposes. The final device can be scaled up in size with addition of UVC emission units in order to accommodate carry-home items of various sizes.

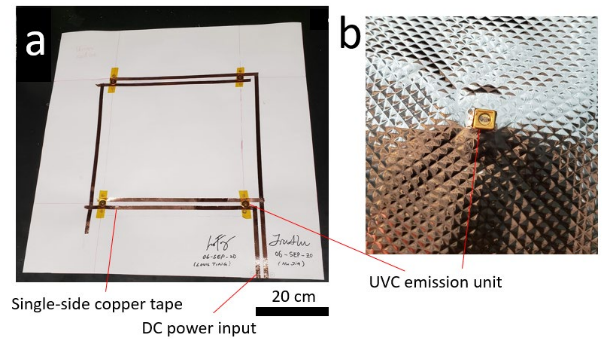

FIGURE 2: Test prototype: a) Image of non-reflective side of wrap featuring the diamond film sheet and copper tape wiring for 4 UVC emission units. b) Image of a UVC emission unit on the reflective side of the wrap.

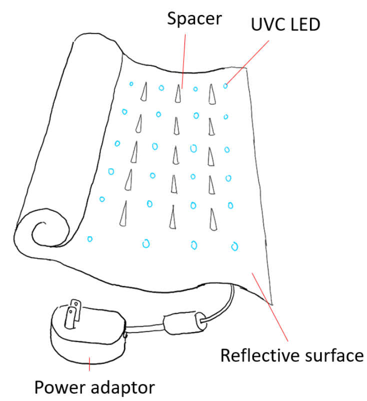

FIGURE 3: Drawing sketch of scaled up device with more UVC emission units on the reflective surface of the flexible wrap installed with spacer and power adaptor.

2.1 Experiment Design

Three assembly prototypes consisting of different 275nm UVC LEDs were used in this experiment to evaluate the feasibility of design to accommodate different LEDs.

Prior to fabricating the assembly prototypes, the output power, P of each individual UVC LED was measured by subjecting the LEDs to 6-V voltage input. Power measurements were obtained using a photometer (Thorlabs, PM100D) equipped with sensor probe (Thorlabs, S120-VC, 200-1100nm) placed directly above the LED. The photometer wavelength setting was set at 275nm ± 5nm prior to measurements taken.

The area of UVC light projection, A by a single UVC LED on flat surface (**Fig. 4a**) is calculated using **Equation 1**. To solve for required distances between LEDs and to flat surface, **Equation 2** was generated by equating the formula of A. In this case, the UVC light intensity, I was held constant at 599 $\mu W \cdot s/cm^2$ ($19.97 \mu W/cm^2$ at 30 seconds), at which the coronavirus surviving rate is 12.2% ± 7.2% [4].

With the measured power P, the minimum height between the LED and targeted surface, h was determined by using **Equation 3**. The value of h also represented the height of the custom flexible PVC spacers (**Fig. 4a**). The distance between two adjacent LEDs, d was determined based on the height h (**Fig. 4b**)

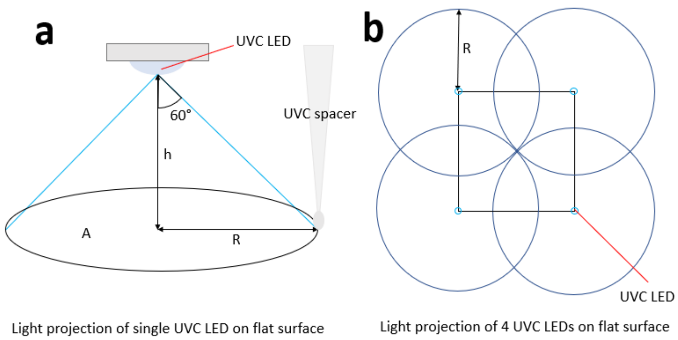

FIGURE 4: UVC LED Light Projection: **a)** UVC projection produced by a single UVC LED onto flat surface. **b)** UVC projected area by four UVC LEDs with a distance $d = \sqrt{2}R = \sqrt{6}h)$ between two adjacent LEDs.

$$A = \pi R^2 = \pi(h \ \tan \tan 60°)^2 = 3\pi h^2 \_\_\_\_\_\_ (1)$$

$$I = \frac{P}{3\pi h^2} \_\_\_\_\_\_ (2)$$

$$h = \sqrt{\frac{P}{3\pi I}} \_\_\_\_\_\_ (3)$$

$$I = \frac{599 \ \mu W \cdot s/cm^2}{T} \_\_\_\_\_\_ (4)$$

TABLE 2: LEDs used, Measured output power, Distance between LEDs and Height between LED and surface

	Source, Item #	Measured Output Power, P	Height of LED to surface, h	Distance between LEDs, d
LED #1	Shenzhen Tiancheng Lighting Co, P/N TL3535 UVCF10-2CXX	*8.0 mW*	*6.5 cm*	*22.51 cm*
LED #2	Shenzhen Learnew Optoelectronics, P/N LN-SMD3535-UVC-P1	*10.0 mW*	*7.2 cm*	*28.48 cm*
LED #3	Shenzen LauXinRui Technology, P/N CP3535SMDUVCAF-275	*8.0 mW*	*6.5 cm*	*22.51 cm*

To test the assembly prototype (**Fig. 2**), power was measured at specific far points p_0, p_1, p_2, p_3 and p_4 (**Fig. 5a, 5b**). The measurement points were selected as they represent the farthest positions from the LED to the target surface, where the power is expected to be lowest at worst-case. For test acceptance criterion, the light intensity obtained through measurement of power and area must exceed 19.97µW/cm² for t=30 seconds.

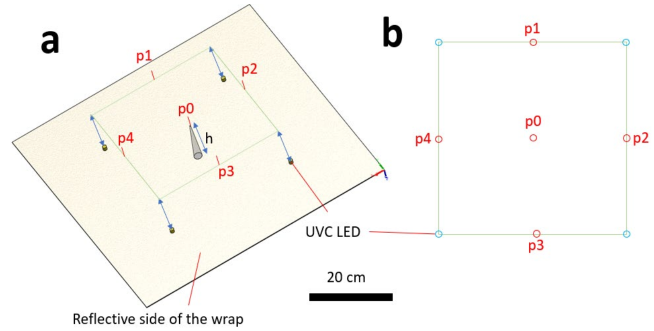

FIGURE 5: UVC Intensity Evaluation Points: **a)** 3D sketch of measurement points p_0 - p_4. **b)** 2D sketch of measurement points p_0 - p_4 relative to LED units.

3. RESULTS AND DISCUSSION

Table 3 summarizes the light intensity results obtained by LED used. All results obtained exceeded the pre-defined minimum light intensity of 19.97 µW/cm². This concluded that the output of the prototype design has successfully met the requirements for surface sanitization.

TABLE 3: Measured Light Intensity at 6-V input by LED used

	Average Light Power, P at 6-V	Calculated Light Intensity, I for t=30 seconds
LED #1	*19.25 µW*	*27.17 µW/cm²*
LED #2	*24.72 µW*	*34.89 µW/cm²*
LED #3	*19.96 µW*	*28.18 µW/cm²*

See **Figure 6** for the concept drawing of the flexible UVC wrap. Users are expected to sanitize the surface of carry-home items effectively and conveniently by:

1) wrapping the UVC wrap around the item,
2) activating the switch-operated 30-sec UVC emission operation
3) removing and folding or rolling up the UVC wrap for ease of storage.

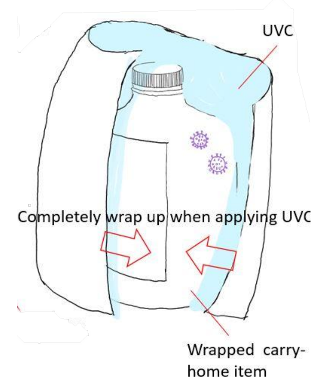

FIGURE 6: Concept drawing of UVC wrap device used to sanitize surface of carry-home item. For reference only.

For future work, we will continue all development tasks to achieve design freeze following applicable verification and validation testing. To verify the device's effectiveness of inactivating the COVID-19 virus, we will seek opportunities to collaborate with a certified laboratory for testing using microbial specimens on representative surfaces such as plastic, wood and metal. To verify the adaptability of the device to the various surface topologies and working environments, the device will be tested on considerable selections of common carry-home items.

Validation testing of the design will involve identified individuals within representative end user groups to establish by objective evidence that the device is capable of meeting predefined user needs. While it is acknowledged that range of convenient device has potential for wide range of applications, the current scope of testing is narrowed to just carry-home items as part of a planned commercial strategy. Other applications, including but not limited to sanitization of medical instrument, wound and room space sanitization, will be explored to be adapted to the current device design [6, 7, 8].

4. CONCLUSION

Preliminary testing has shown that the UVC wrap is capable of delivering sufficient UVC light to deactivate coronavirus on contaminated surfaces. The intended use of this device is to provide a consistent and effective method for users to sanitize potentially contaminated carry-home items. Further verification and validation testing of the final design will follow to provide further objective evidence in supporting the claim. Following successful completion of all development activities, our goal is to launch this device to be introduced into households and contribute its role in response to the COVID-19 pandemic.

ACKNOWLEDGEMENTS

N/A

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