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UVC Integrated Knitted Heating Textile Blinds for Self-Sanitization in Healthcare Environments

Sonali Rath[1], Hara Prasada Tripathy[2], Priyabrata Pattanaik[2], Dilip Kumar Mishra[2]*

[1]*Center for Biotechnology, Siksha 'O' Anusandhan Deemed to be University, Bhubaneswar 751 030, Odisha, India.*

[2]*Faculty of Engineering and Technology (ITER), Siksha 'O' Anusandhan Deemed to be University, Bhubaneswar 751 030, Odisha, India.*

**Corresponding author mail id: haraprasadtripathy@soa.ac.in*

Abstract: Infection can only be prevented by routine sanitization process. Surface hygiene systems are remained underexplored. High-touch point cleaning is very much essential in healthcare systems. From primary to emergency healthcare, blinds are most common high touch surface. Antimicrobial based blinds are used to disrupt microbes and inhibit microbial growth. However, the dead microbes, oils and dusts are still sits on the blind's surfaces. Repetitive increase of the event creates a layer over the blinds and thus again reverse the process by increasing the microbial growth. Recent developments on embedded heater based thermal sanitization though widely unused but has potential to explore by adding ultraviolet C light emitting diode (UVC LED). UVC is germicidal. UVC photons destroys the DNA and RNA of the pathogens by penetrating the thin walls of bacteria and the protein coats of the viruses. Conducting yarn based knitted heaters has the advantages like uniform, low power heating with typical temperature ranges from 40 to 120 □ enables for wearable, thermotherapy and industrial applications. Both UVC and Knitted heaters are chemical free methods for sterilization. Controller based UVC and Knitted heating textile integrating technologies into blinds may inhibit microbial growth. This combined system may revolutionize by facilitating chemical free, flexible and programmable dual mode self-sanitization process. Significant research aspects open up after adding the above including washability, durability, hospital cleaning protocol and safety standards. Addressing the above research aspects can lead to develop next-generation self-sanitizing smart blinds by reducing pathogen transmission, inhibit microbial growth, enhance environment hygiene in healthcare industries.

Keywords: Ultraviolet C (UVC), Knitted Heater, Self Sanitization, Microbial Growth, Healthcare

1. INTRODUCTION

In Healthcare, laundering and disinfection processes utilize a variety of chemicals. This often includes a range of aggressive oxidizing agents and surfactants such as sodium hypochlorite, hydrogen peroxide, peracetic acid, caustic soda, nonylphenol ethoxylates, and quaternary ammonium compounds

[1,2]. Sanitization is an essential task in the healthcare industry [3]. At present, passive cleaning of the blinds has slow kill rates [4]. Leaching of the antimicrobial chemical coating and the development of antimicrobial resistance are leading to skin irritation [5–7].

Knitted heating fiber combined with UVC system enables the blinds to combat the microbial spread [8]. This transformation has the potential to act as sterilization barrier on the high-touch surfaces which are commonly used in cubicles, privacy screens, table and bed side portions. These surfaces are highly vulnerable to infection [9–11]. Such integration improves material functionality while preserving flexibility. Periodic UV light exposure may help to clean the blinds by deactivating any infections that the heating elements haven't successfully sterilized when they interact with bacteria trapped in the fabric [12,13]. Using commercially available blind fabrics with silver nanoparticles with antimicrobial capabilities is an affordable technique for removing airborne viruses as they come into touch with one another [14]. These materials are more effective than ordinary fabrics at neutralizing germs because they can be triggered by light or heat [15]. Many studies have fully examined the vital role they serve in preventing the spread of airborne viruses, as well as the ways in which textile improvements and UVC with thermoregulation may improve fabric effectiveness [16,17]. This suggests a significant research gap in the literature that needs to be filled.

This study introduces a new method by experimenting with simple embroidered designs and carefully adding heating elements to textiles. It might be feasible to ensure more equal heat distribution and better control over the placement of heating elements because embroidery offers a high degree of precision when putting conductive materials. Conductivity and heat-generating potential tests are crucial for assess Thus, the purpose of this study is to explore practical ways of implementing UVC and thermoregulation technologies in textiles by using embroidery techniques and electronically controlled heating elements. The study also focuses on how these technologies can be integrated into fabric designs to enable effective self-sanitization. In addition, this work examines the electrical safety of UVC-integrated, thermoregulated blinds, with particular attention to minimizing potential electrical hazards.ing the safety and effectiveness of these designs. This research brings out interesting potential for hospital hygiene technology by integrating fabrics with UVC with heating elements, especially in situations where sanitization and safety are essential.

2. ASSEMBLY

2.1 Materials for Heating Element

Conductive and heating component used in this textile heater is an SS316L stainless-steel yarn (Konfitex, China; Item No. SFB-3). Yarn is made of three twisted bundles of fine 316L stainless-steel filaments, each measuring about 8–12 μm in diameter. This twisted, multi-filament structure makes the yarn flexible and mechanically strong, which is especially important for embroidery into fabrics that are regularly bent, handled, or exposed to repeated heating cycles. At the same time, this structure helps maintain uniform electrical conductivity along the length of the yarn, allowing heat to be generated evenly across the textile surface. The electrical resistance of the yarn ranges from 2.0 Ω to 2.68 Ω, which enables efficient heat generation at low operating voltages and allows precise temperature control. The yarn can safely withstand temperatures up to 650 °C, far exceeding the levels required for self-sanitization, thereby ensuring stable and reliable operation. In addition, SS316L stainless steel is well known for its resistance to oxidation, acids, alkalis, and repeated washing. These properties make the yarn highly suitable for long-term use in healthcare textiles, where durability, electrical stability, and consistent heating performance are critical. Due to these combined properties, SS316L yarns gained wide use in heating garments, gloves, blankets, and vehicle seat heaters. Their high flexibility and stable resistance make them ideal for new applications such as self-sanitising healthcare blinds. In this work, the SS316L yarn acts as a thermally conductive channel within the fabric structure, allowing for regulated temperature rise for microbial inactivation while preserving textile comfort and structural stability.

2.2 Experimental embroidery design of the heating element

The substrate size is fixed at 10 cm × 10 cm (Figure 1). These fabrics are uniformly cut through the laser cutter to get the straight and uniform shapes of the rectangles. In these rectangular-shaped fabrics, the heating patterns are embroidered by the weaving machine. Utilizing the saddle stitch technique, known for its durability and strength, is ideal for creating robust electrical connections within the textile substrate. The 3 mm stitch length helps maintain a consistent distance between stitches, ensuring uniformity in electrical resistance and, consequently, even heating across the electrode.

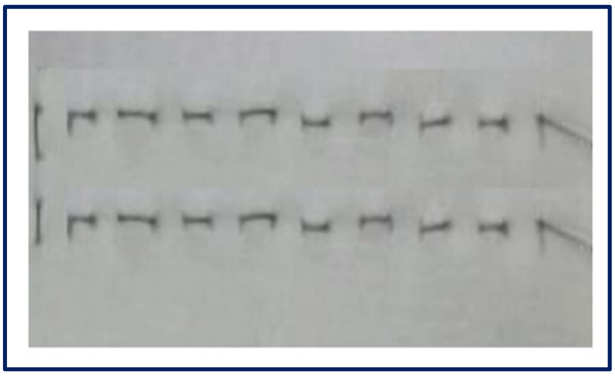

Figure 1. Simple embroidered Parten on fabric

Using AutoCAD, the design has created and then exported as a vector file in the drawing exchange format. This file was then imported into the technical embroidery machine's proprietary stitch digitizing software, where it has transformed into the proper transport code file for embroidery in a technical embroidery machine. For experiment blind’s textile has procured from a fabric store and embroidered with a simple design. The stainless-steel yarn is utilized in all designs.

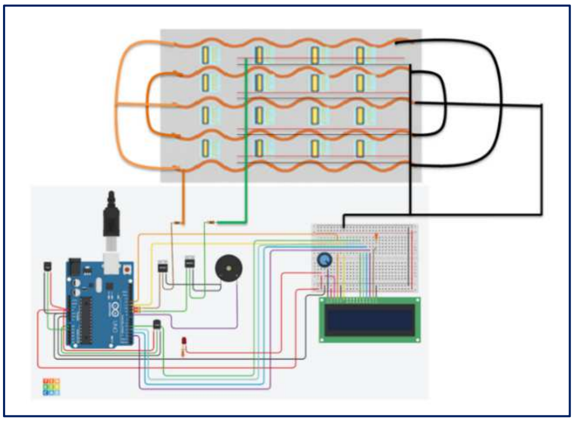

Figure 2. UV-C and Heater driver circuit with microcontroller

2.3 Experimental Setup

A regulated power supply (3–12 V) energized the textile heating elements through a protected heater-driver circuit controlled by an Arduino Uno microcontroller. The controller served as the central unit for regulating both the

SS316L yarn–based heating elements and the integrated UV-C modules, enabling automated sanitization cycles. A closed-loop control algorithm maintained the target temperature required for microbial deactivation while preventing overheating. Electrical characterization was performed using a multimeter, and thermal response was monitored using a temperature sensor. The system was first modeled in TinkerCAD and subsequently implemented as a physical prototype with conductive threads embroidered into textile blind fabric (Fig. 2). The temperature rise increased with current, consistent with Joule heating, while heating-element geometry had minimal influence compared to material thermal properties. A target temperature of 150 °C was selected to ensure effective self-sanitization beyond the commonly reported 60–70 °C range.

3. RESULTS AND DISCUSSION:

3.1 Microbiological Efficacy

The integrated UVC-Heated Textile system demonstrated superior germicidal efficacy compared to either UVC or Heat treatment alone. The proposed system has three different treating conditions likely UVC only, Heat only and combined system respectively.

Table 1. Comparative antimicrobial efficacy of UV-C, thermal, and combined UV-C–thermal treatments against Staphylococcus aureus bacteria

Treatment Condition	***Target Microorganism***	***Temperature***	***Exposure Time***	***Average Log Reduction (LR)***
Control (UVC Only)	*S. aureus*	25℃	10 min	1.8±0.3
Control (Heat Only)	*S. aureus*	70℃	10 min	2.1±0.4
Combined System	*S. aureus*	70℃	10 min	4.5±0.2

Experiment has carried out by using cultured staphylococcus aureus bacteria from laboratory on a fabric shown in figure 1. UVC Only treating condition is carried out at 25℃, whereas other treatments are done using 70℃ for a period of 10 minutes. The combined treatment achieved a 4.5 Log Reduction (LR) against *Staphylococcus aureus* in 10 minutes at 70℃. The detailed values are noted in the table 1.

3.2 Textile integrity and safety

The electrical resistance of the stainless-steel yarn elements showed a negligible change after 100 sterilization cycles at 90°C confirming the long-term durability of the heater element. Applying UVC dose and several thermal exposures, the textile blinds maintain its original breaking strength within limits of ±5\%.

4. CONCLUSION

Proposed UVC integrated knitted heating textile blind system represents a novel step upward to high-touch surface disinfection. After combining user controlled knitted heater with ultraviolet irradiation addresses key challenges associated with conventional methods, particularly line-of-sight limitations and the complex textures of textile surfaces. This hybrid approach shows strong potential for infection control in demanding healthcare environments, such as hospital window blinds and privacy partitions. For this technology to be successfully adopted on a wider scale, several technical challenges must be addressed, including appropriate material selection, efficient power management, and scalable manufacturing processes. These factors are critical to ensure that the final textile products remain safe, comfortable, durable, and effective during long-term use. The integration of advanced functional materials into textile heaters has the potential to redefine how fabrics contribute to human comfort and health, extending beyond healthcare into applications such as outdoor clothing, therapeutic textiles, and everyday wearable systems. Continued development and refinement of UV-C heated textile platforms are expected to further embed intelligent heating and sanitization capabilities into fabrics, enhancing both functionality and overall user experience.

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