Prospective of Germicidal Far UV-C in Face Masks and PPE

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Abstract: The global pandemic, COVID-19 has already created an awareness of the imprescindible use of face masks and personal protective equipment (PPE). Even though vaccines are already developed, a strong inclination and fear for protection and prevention would be urged for times to come. This is mainly because the novel coronavirus (SARS-CoV-2), and its new variants are here to stay and will not be fully eradicated any soon. We have now learned to live with it and habituated ourselves with social distancing, face masks, PPE, etc. Seemingly, the current physical protection protocol is not enough. Can we eliminate the virus in a short span before they reach inside and play games of life and death? Though ultraviolet emission, specifically UV-C in 200-280nm is an established technology for disinfection, direct exposure is hazardous to humans. Recent research on far UV-C seems (207-222nm) quite promising; they are much safer, efficiently germicidal even at a much lower intensity and exposure time. Can we retaliate now with functional wearables, face masks, and PPE? It's an open challenge now for the material scientist.

Keywords: COVID-19, critical materials, fabric, fibre, functional, radiation effects, Far UV-C.

PROSPECTIVE

"Neither the sudden shock of battle nor the long-drawn trials of vigilance and exertion will wear us down. Give us the tools and we will finish the job" quotes Winston Churchill. Whereas, Chanakya, the great Indian philosopher, and strategist say "A debt should be paid off till the last penny; an enemy should be destroyed without a trace". The novel coronavirus (SARS-CoV-2) has already "taken control" over the world and we are now living in such a society, where social distancing and digitalisation have become integral parts of the "new normal" life. Textile masks can of course reduce the infection rates and spreading. But, there is much more to do, thinks the Textile Technologists and Biological Scientists who keep the fire burning in their heart to "destroy coronavirus without a trace".

The burning question here is: can we use the germicidal Far UV-C source directly on face masks and PPE? How safe are they? If so, can these fatal viruses be easily killed by these functional wearables before they attack us? Can it provide a universal protective solution for viruses of any kind?

Building further upon the current literature, it is high time to develop germicidal face masks and PPE for the health care professional with a 100% guarantee of eliminating these super spreaders. In fact, the Covid-19 virus size (60-125nm) is smaller than the pores of current N95 or N99 Masks. Affordable germicidal masks invented so far, have limited market attention, due to various complexities.

Among numerous disinfection procedures, the Centres for Disease Control and Prevention (CDC) in April 2020 regarded Upper room Ultraviolet Germicidal Irradiation (UVGI), H2O2 vapour, and moist heat to be the best options [1]. The UVGI has obviously an upper hand as it is chemical-free and effective treatment times are less than 5 min. As the UV-C disinfection method is being used frequently, some investigations in the narrow band [far UV-C light (207-222 nm)] elucidate clearly that far UV-C can kill microorganisms efficiently without any harm to human cell; they cannot enter to thicker human stratum corneum (5-20 μm) or mammalian nuclei, but destroy bacteria and viruses of the small thickness of few <μm [2-5]. Far UV light at 222 nm "hardly penetrates the outer layer of skin," says David Sliney, retired manager of the U.S. Army's Laser and Optical Radiation Program at the Army Public Health Center, near Baltimore. "It's heavily absorbed by protein. But there is some evidence that it may even be more effective against airborne viruses" than other UV

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light. The wavelength appears to be safe for the eyes as well because it penetrates no deeper than the layer of tears that coat the eye. A study on prolonged far-UV exposure to albino rats, 2019 in Japan found no induced skin or eye damage [6].

N95 and SN95 mask efficacy in terms of physical, chemical, virus protection ability, and safety is reported to be unaffected with UVGI of 254-265 nm UV-C at 1 and 10 J/cm2 [7]. Silverman et al. [8] stated that 1 J/cm2 UVGI (100−280 nm) is quite more than enough to inactivate > 99.9 % of many kinds of influenza and coronavirus in the water; they disrupt DNA and RNA and forms pyrimidine dimers. A recent study by Buonanno et al. [4] on far UV-C light (207-222 nm) at 1.7 and 1.2 mJ/cm2 demonstrates that they efficiently kill >99.9% of the pathogens without harm to exposed human cells or tissues. Currently, for viral inactivation, a continuous far UV-C exposure limit of 3 mJ/cm2/hr in public locations ensure 99.9% viral inactivation in ~ 25 min; an even lower dose of 1.7 and 1.2 mJ/cm2 inactivates 99.9% of aerosolized alpha coronavirus 229E and beta coronavirus OC43.

It is a well-established fact that functional textiles, conducting yarns, medical textiles, nano-composites, wearable e-textiles, and energy harvesting textiles are making major inroads into human life ensuring smart performance, protection, and comfort [9]. These technologies could be explored to a fuller extent to design and ensure a new dimension of reusable and cost-effective UV-C enabled masks and PPEs with coronavirus annihilation and human protection properties. The exposure risk of UV-C, generated in situ in the mask, could further be prevented by fabricating it with multi-layered fabrics with multiple functionalities, while the inner conductive yarn layer with UVGI function; a cotton fabric can have a high UV

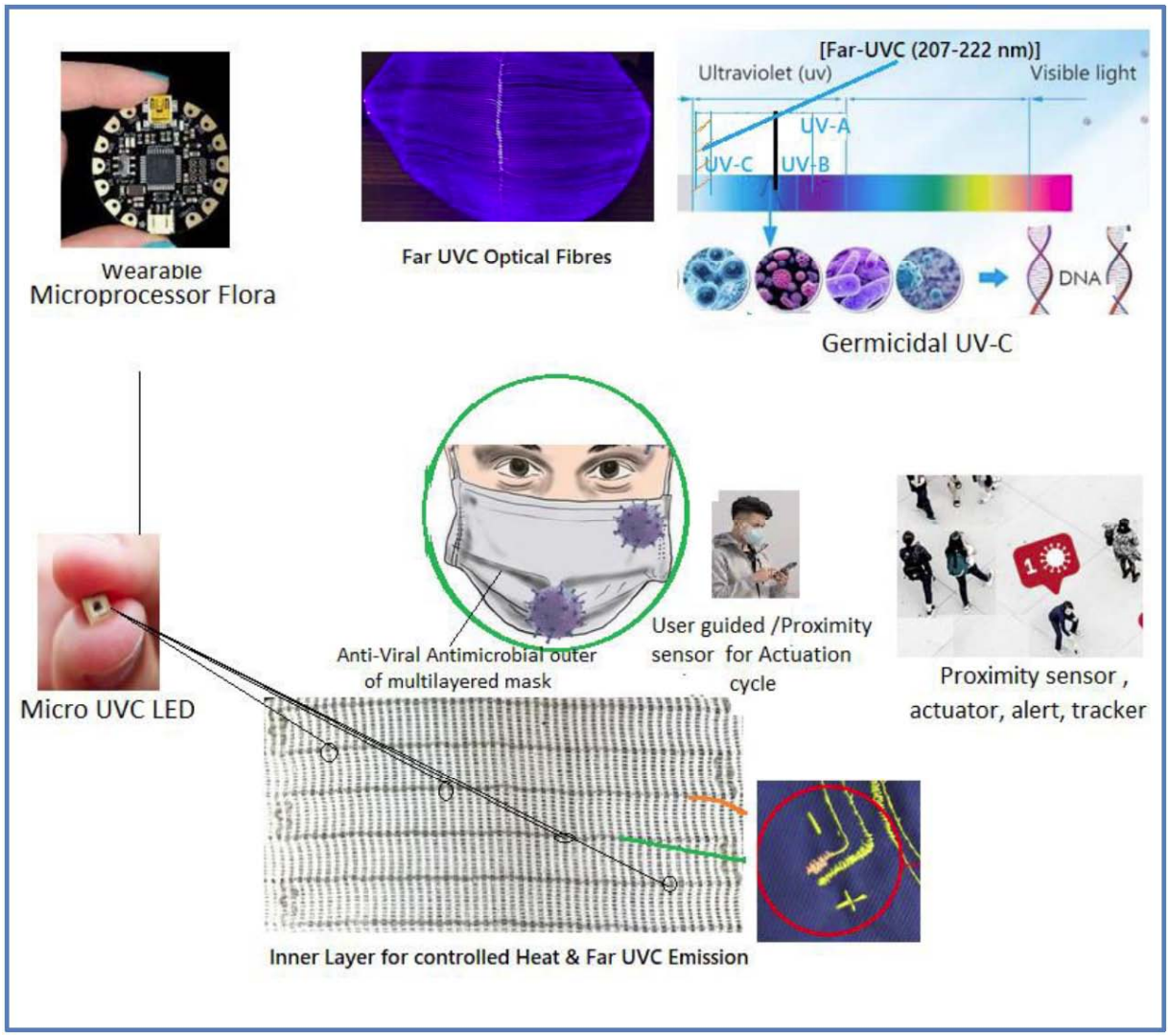

Figure 1: Germicidal Far UV-C Mask/PPE Prospective.

protection factor (UPF>48) by nano-finishing [10,11] with very low cytotoxicity and moisture management properties for better comfort [16]. In addition, heating by thermo-conductive yarns with micro UVC LEDs is quite possible currently (Figure **1**) which could be triggered by wearable e-textiles and tiny microprocessors. However, flexible fibres for emitting far UV-C or the development of optical fibre that can propagate UV-C are still under the domain of research.

An interesting prospective was discussed in 2014 on the possibilities and challenges of the development of hollow optical fibre for laser-guided UV light [12]. Few other techniques such as tiny UV-C lights and optical fibres or other fibres for UV-C generation are also reported [13,14]. They could be powered by common gadgets such as power banks, laptops, batteries but not limited to other equivalent sources like a solar or piezo-electric wearable or energy harvesting textile concepts. It is highly expected that the synergistic effect is possible with intelligent management of far UV-C along with heat for optimal safety.

Another million-dollar question is “can we dye or finish textiles for the hypsochromic shift for reflecting far UV-C”? In addition, several functional finishing techniques already available for the development of anti-viral and antimicrobial textiles, those could be used in the outer layer. Strategies for Antiviral Coatings was explained lucidly explained by pemmada *et al*. [15].

Let us think further, the germicidal emission cycles with heat could be actuated by a proximity sensor or user, made up of wearable functional textiles, that can explore tracking in real-time. We are outlining a conceptual prospective in Figure **1**. The thermo- and UV emission regulating cycles could be controlled as per the demand; say by proximity IR sensors or the mobile apps that alert when a Covid-19 patent is nearby and help real-time data monitoring for further research.

This short communication is intended to thrust research in masks and PPEs for smart protection of humans and the elimination of coronavirus, at least those in our vicinity. The concept trial in the Thinker cad model and video were explained in the supplementary file.

CONFLICT OF INTEREST STATEMENT

We, the authors, declare that we have no conflict of interest.

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