Reusable Three-layered Facemask Developed by CSIR-CMERI

CSIR-CMERI Durgapur has developed re-usable **three-layered facemask**, to combat novel Corona virus of COVID 19. Even though social distancing should be the standard protocol in the current scenario, use of facemask is another preventive measure to stop the exponential spread of the lethal virus or the '*Invisible Enemy*'. In this hour of crisis to stop the exponential spread of the lethal virus, CSIR-CMERI has worked extensively in developing facemasks, which can effectively prevent transmission bacteria or viruses inward or outward and can be reusable and cost effective.

It is considered that the viral respiratory infections not only spread by direct contact, but also it may spread through the droplet transmission. The droplets released during coughing and sneezing may be of different sizes, larger one with 0.1 mm or more and the smaller droplets with size < 10 μm (*Nature Medicine, 2020, DOI: 10.1038/s41591-020-0843-2*; *Current Opinion in Virology, 28, 2018, 142–151*). While the larger droplets settle down within 1.5 m range, the smaller droplets containing viral content may have suspended in air and travel longer distance, say 6 m. Furthermore, researchers found that viruses may remain infectious in aerosols for 3 h (*N. Engl. J. Med. 2020, DOI: 10.1056/NEJMc2004973*). A recent report says wearing of surgical masks reduce the overall viral RNA copies in exhaled breath and cough aerosols by 3.4 folds, which indicates the importance of wearing of facemasks in current situation (*PLOS Pathogens, 9, 2013, e1003205; Nature Medicine, 2020, DOI: 10.1038/s41591-020-0843-2*).

One of the most important features in facemask is the hydrophobicity or water repellent nature of mask materials. The first and foremost thing for any facemask should be its ability to restrict droplets effectively during sneezing or coughing. In order to test the water repellent ability, the wettability test was performed by contact angle measurement at the surface of the non-woven polypropylene layer with a specific pore size as the outer layer of facemask. The contact angle is an angle that a liquid creates with a solid surface while the liquid comes in contact with a solid surface. The measurement indicates the characteristics of solid surface and its interaction with the liquid. Those interactions are described by cohesion and adhesion forces, which are nothing but intermolecular forces. The contact angle is measured indirectly by the tangent profile at the liquid-solid interface with a 6 μl distilled water droplet on the 0.3 mm thick polypropylene fabric sample surface (Figure 1). The measured contact angle on our developed mask surface is found to be ~125º, which is even higher than that of N95 surface (114º). The hydrophobicity of any surface is determined by the contact angle >90º, which indicates cohesive forces higher than the adhesive forces. This proves that our developed mask surface is highly hydrophobic or water repellent in nature and likely to be able to restrict droplet effectively.

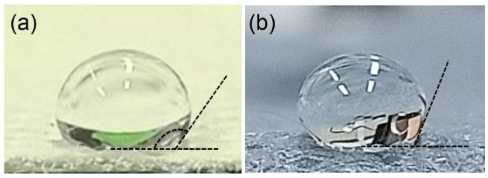

Figure 1: Contact angle measurement on the surface of (a) non-woven polypropylene and (b) commercially available N95 facemask

The choice of non-woven polypropylene layer used in the mask is a very important aspect, which should be looked into. The pore size of the materials surface is one of the determining factors to decide the penetration of droplets released during coughing and sneezing. In order to study the pore size and get the information about the distribution of fibers, Field Emission Scanning Electron Microscope (FESEM) of samples were analysed and also compared with cotton

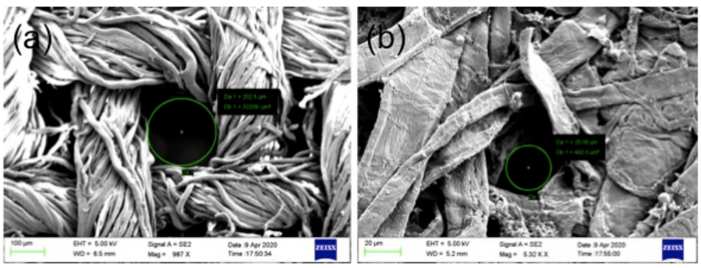

Figure 2: FESEM images of (a) cotton fabric and (b) tissue paper

fibers as well as tissue paper (Figure 2). The later two are being used extensively in majority of households for making makeshift masks. The microstructure and detail pore size analysis reveal that the cotton cloth/fabric has mean pore size greater than 200 μm, whereas the mean pore size of tissue is 30 μm. However, since these two materials have been found to be hydrophilic, they may not be suitable for making face masks under prevalent condition of COVID-19 pandemic as the virus may travel through water droplets. On the contrary, microstructures of non-woven polypropylene (PP) fabrics indicate compactness and distribution of fibers with a proper pore size range for different qualities of PP fabrics.

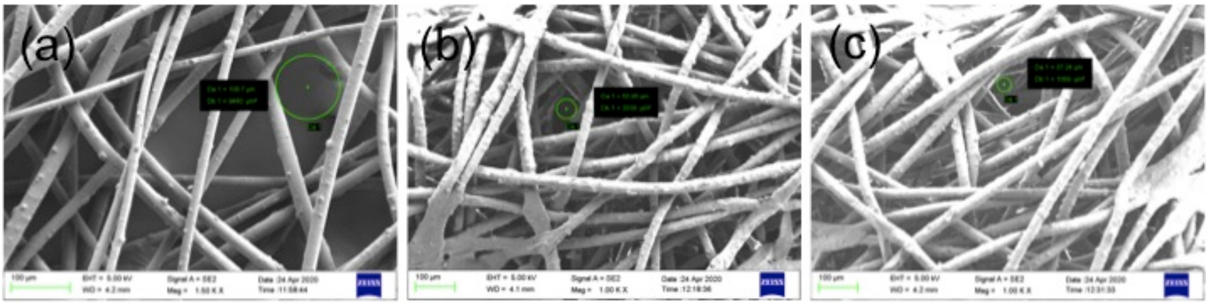

Figure 3: FESEM images of PP layers of different pore size ranges of (a) > 100 μm, (b) 55±5 μm and (c) 35±5 μm.

The reusability of mask materials has further been checked and compared with the cotton fabric made facemasks. It has been found that after first wash, the polypropylene cloth gets stretched marginally increasing the pore size from 35±5 μm to 40±5 μm, thereafter it remains constant even after three washes. On the other hand the poplin cloth gets further enlarged owing to damage in nearby fibers, and this gets severed with every subsequent washes. Tearing of fibers could be observed after third wash (Figure 4). This brings us to the fact that PP fabric can be reused for much longer duration compared to poplin/cotton masks without compromising the quality much.

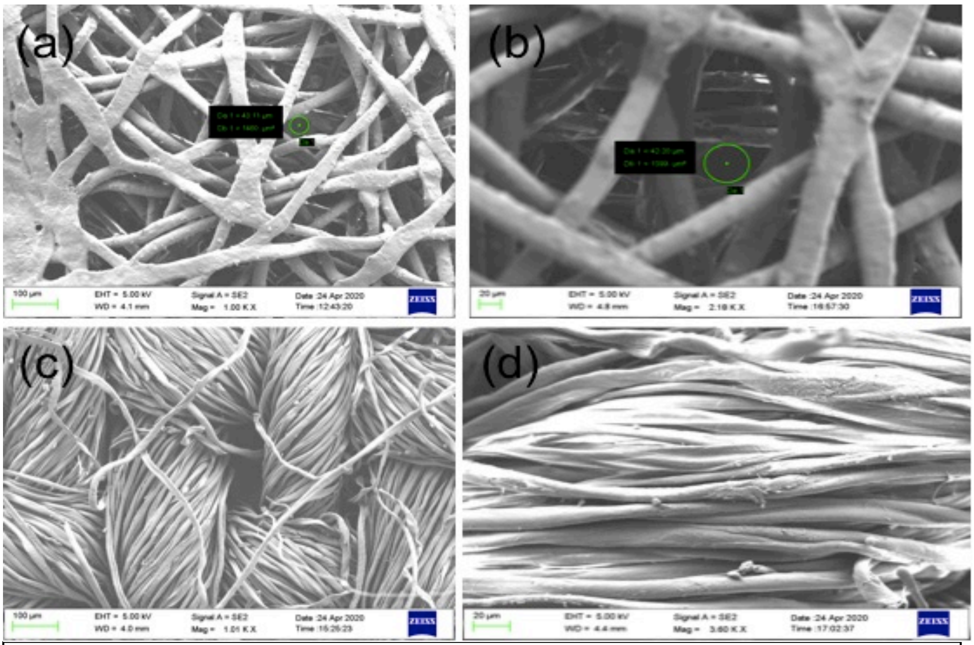

Figure 4: PP vs. Cotton fabric: Microstructure of PP fabric after (a) 1st wash and (b) 3rd wash and cotton fabric after (c) 1st wash and (d) 3rd wash.

We have also analysed the effect of stitching as PP fabrics in masks were stitched by using needle and cotton threads. The anticipation of enhancement of pore size due to the insertion of needles and cotton threads can be ignored out as the FESEM images in the stitched region show no such evidence of pore size enhancement.

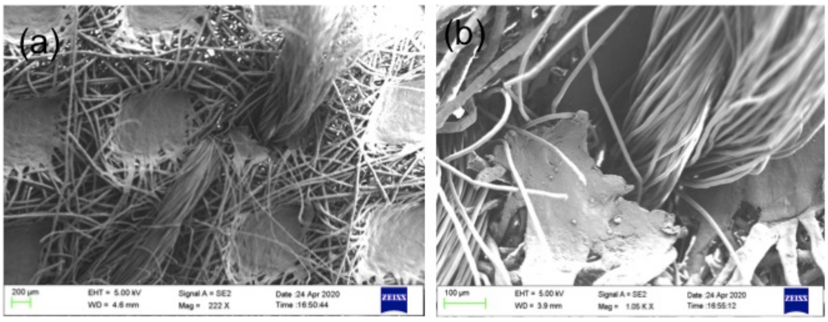

Figure 5: Microstructures of Stitched region showing no apparent increase in pore size

To ensure the fact the developed mask is capable enough to prevent bioaerosols, i.e., aerosols containing bacteria and viruses, bacterial filtration efficiency (BFE) as per the *ASTM standard F2101* should be studied. The tests are carried out by the aerosolized bacteria, *Staphylococcus aureus* – a human pathogen, at a flow rate of 28.5 L min^{-1}. As tested by The South India Textile Research Association (SITRA), Coimbatore our facemask specimen is able to show the BFE value of 79.5%.

Further, the particulate filter efficiency (PFE) tests must be carried out as a quality indicator for facemasks developed. The PFE is carried out with dried air passing through an atomizer followed by the charge neutralizer to produce neutralized aerosol of 0.3 µm diameter at a challenge velocity of 28 lpm. As tested by SITRA, our facemask specimen shows the value of PFE as high as 91.76% indicating high restriction of hazard particulates. The facemasks are also tested and ‘’ for splash resistance to measure the prevention against the splashes of blood and body fluids from the patient as tested by SITRA. The breathability of facemask must be checked to ensure the fact that the developed masks are wearable for longer period of time. Thereby. the pressure differential is a measure of the air flow resistance of the mask and is an objective measure of breathability. The higher the pressure differential, tougher it is for the wearer to breathe. The test result of differential pressure of 12.0 Pa cm^{-2} as per the *IS 16289:2014 Annexure C* indicates easy breathability of facemask developed.

Other than the characteristic features of facemasks, CSIR-CMERI scientists have also taken care of the sterilization of masks after completion of development process. It is known fact that amongst various methods, treatment with UV-C with the wavelength of 254 nm is one of the most effective way to decontaminate masks from viruses as well as bacteria. Knowing this fact, currently CMERI has created the facility to sterilize 6000 masks per day by effective exposure of UV-C lights. However, during the whole process, one must avoid direct exposure UV-C light. Finally, the sterilized masks were properly sealed and packed maintaining the hygiene.

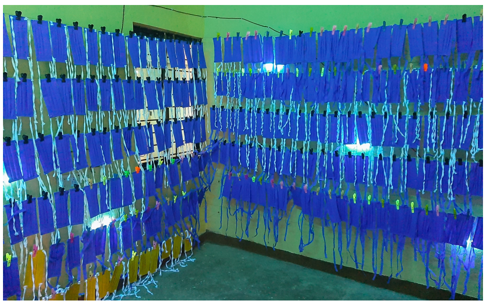

Figure 6: Developed facemasks being sterilized by UV-C light at CSIR-CMERI.

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