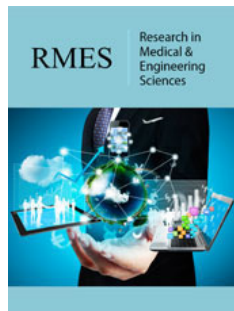


Protection of Very Small Particles Such as Viruses and Bacteria by Washable and Wearable Z-Nanofiber Sheet Mask

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ISSN: 2576-8816



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Submission: 📅 February 24, 2021

Published: 📅 March 08, 2021

Volume 9 - Issue 2

How to cite this article: Akihiko Tanioka, Mitsuhiro Takahashi, Tsuneo Hanada. Protection of Very Small Particles Such as Viruses and Bacteria by Washable and Wearable Z-Nanofiber Sheet Mask. Res Med Eng Sci. 9(2). RMES.000707. 2021. DOI: [10.31031/RMES.2021.09.000707](https://doi.org/10.31031/RMES.2021.09.000707)

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Opinion

The diameter of the COVID-19 virus is considered to be about 50nm to 150nm, and the aerosol diameter containing it by cough about 300nm. Usually, masks are indispensable for preventing both virus spread and inhalation. There are various types of masks from woven to nonwoven fabrics on the market, and the protective effect to virus varies from a few percent to over 99%. In general, the performance of a mask can be represented by the Particle Filtration Efficiency (PFE) and Pressure Drop (PD) similar to an air filter. PFE corresponds to a measure of virus protection and PD to ease of breathing. Therefore, better performing masks have higher PFE and lower PD. PFE and PD are in a strong relationship with each other, that is, whenever we try to increase PFE, PD will increase. Generally, electrets are given to increase PFE in keeping PD low such as HEPA and ULPA. The electret, however, loses the effectiveness by water vapor in air, etc. Z-nanofiber sheet mask, which is produced by Z-melt spinning method (1) of polypropylene (PP), can solve those problems, because nanofiber can adsorb virus and bacteria by the van der Waals force without giving electrical properties, that is so-called hydrophobic bond, which induces the washable property of the mask. Table 1 shows the PFE and the PD of seven Nanofiber sheet samples of PP. PFE was measured by using the NaCl particles whose diameters are from 25nm to 131nm, where measurement conditions are 100cm² of measurement area, 31.8L/min of ventilation volume, and 5.3cm/sec of flow velocity, respectively. PFE and PD of each sample are more than 99% and less than 70Pa, respectively, which means that we can prepare the non-suffocating mask with high virus capture efficiency [1].

Table 1:

Sample No.	PFE (%)	PD(Pa)
1	99.79	30
2	99.95	60
3	99.5	26
4	99.9	70
5	99.5	60
6	99.28	34
7	99.08	62

Table 2 shows the PFE of ten different Z-nanofiber sheets of PP before and after washing. For after washing the data of every 10 times are listed and it is repeated 100 times by soak washing for 10min in adding the commercial laundry detergent of 0.35g/L. After drying at 37 °C the PFE was measured at the same condition in Table 1 and the most important thing is PFE keep almost the same value after 100 times washing.

Table 2:

Sample No	PFE(%)										
	Before Washing	Number of Washes									
		10 th	20 th	30 th	40 th	50 th	60 th	70 th	80 th	90 th	100 th
1	99.6	99.3	99.1	99.5	99.4	99.9	99.2	99.5	99.7	99.2	99.2
2	99.4	99	99.3	99.6	99.1	99.5	99.7	99.5	99	99.1	99.7
3	99.6	99.9	99.9	99.3	99.7	99.9	99.6	99.2	99.9	99.5	99.5
4	99.3	99.6	99.3	99.8	99.5	99.7	99.9	99.9	99	99	99.5
5	99.5	99.8	99.9	99.4	99.6	99.4	99.3	99.2	99.2	99.4	99.9
6	99.7	99.9	99.9	99.5	99.8	99.6	99.7	99.6	99.2	99.8	99.1
7	99.6	99.2	99.7	99.3	99.9	99.5	99.1	99.3	99.1	99.7	99.3
8	99.7	99.6	99.9	99.8	99.5	99.3	99.7	99.7	99	99.4	99.3
9	99.5	99.5	99.4	99.9	99.7	99.4	99.6	99.3	99.9	99.1	99.5
10	99.1	99.6	99.9	99.7	99.4	99.7	99.2	99.6	99.9	99.7	99.4

Table 2 indicates the Z-nanofiber filter mask does not change high virus capture efficiency after repeated washing. Figure 1 shows the relationship between PFE and particle diameter from 0.3 to 3.5µm at different treatments. Blue line is the original sample which is not treated (Control), gray one the sample after 5 times washing in the same condition as Table 2 (Washing), orange one the sample which is treated five times in an autoclave for 20min at 121 °C and 2atm (AC). The most important thing is the PFE is increased after autoclave treatment, which suggests that Nanofiber sheet mask increases the virus capture efficiency after anti-virus treatment with heat and vapor.

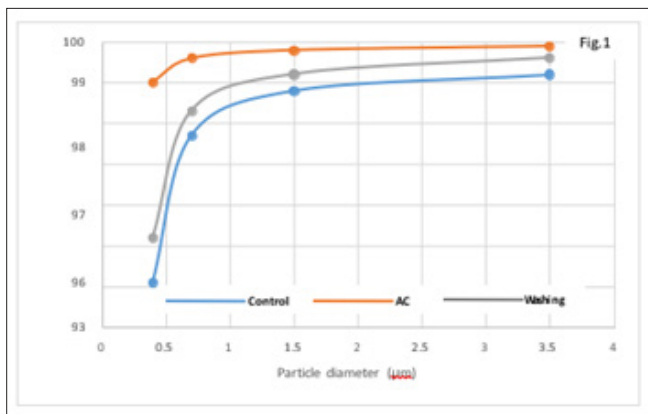


Figure 1:

Figure 2 shows the mask made from the Z-nanofiber sheet of PP whose density is about 60g/m² and thickness is about 5mm as shown in Figure3, and Figure 4 is the SEM image of Nanofiber sheet where the fiber diameter is varied from ca. 100nm to 5 µm. The variation of fiber thickness plays the important role of increasing PFE and keeping PD low while maintaining mechanical strength. Finally, since the Z-nanofiber sheet mask is composed of PP nanofibers, it can be concluded that it can capture more than 99 % of COVID-19 virus, be easy to breathe, and be washed and used repeatedly.



Figure 2:

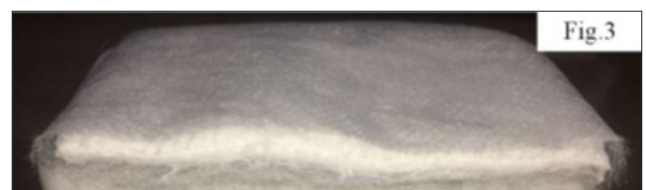


Figure 3:

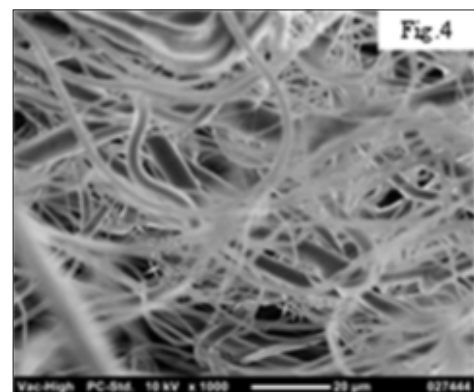


Figure 4:

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