

## **Can N95 facial masks be used after disinfection? And for how many times?**

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### **Summary**

**The COVID-19 pandemic has led to a major shortage of N95-level facial masks, especially in the healthcare environment. We have investigated three promising disinfection methods that may be applied to the recycling and reuse of facial masks: hot air (75 °C, 30 min), UV light (254 nm, 8W, 30 min), and steam (10 min). Using a N95-level meltblown filtration fabric, we determined the following: 1) Hot air applied over 20 cycles did not degrade the filtration efficiency (>95%). 2) UV treatment over 10 cycles did not degrade the filtration efficiency (>95%). 3) Steam treatment requires caution, as the filtration efficiency can be maintained (>95%) within 3 cycles, but the efficiency will degrade to ~85% after 5 cycles, and finally will drop to ~80% after 10 cycles. With respect to the hot air (75 °C, 30 min, 20 cycles), we found that an N95 mask did not suffer any mechanical deformation and the ear straps retained proper elasticity required for use.**

*Note: We would like to share our results with the community as soon as possible. Be mindful that this report is our work in progress, including some of our speculation. We will have more results in the coming days and weeks.*

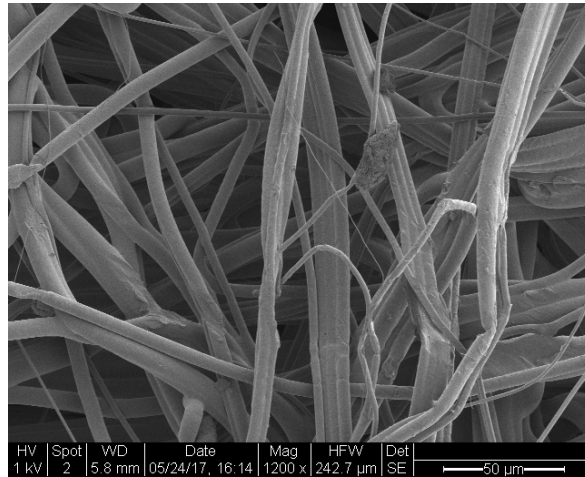
### **1. Introduction and Rationale**

The COVID-19 virus is thought to transmit primarily through respiratory droplets. The size COVID-19 virus is ~0.1  $\mu\text{m}$ , while the size respiratory droplets can be multiple micrometers. However, while the droplet is in-flight, it can shrink due to the evaporation of water. Therefore, it is necessary to have personal protection, especially facial masks, for those in close proximity to patients infected with COVID-19. It is also recommended to wear facial masks when in crowded environments to suppress COVID-19's spread.

The N95-level facial mask is recommended personal protective equipment (PPE) by the Centers for Disease Control and Prevention (CDC) for those in close contact with COVID-19. According to the United States' National Institute for Occupational Safety and Health (NIOSH), N95 refers to >95% efficiency for particle sizes of around 0.3  $\mu\text{m}$ . The equivalent N95 standard in other countries are termed FFP2 (European Union), KN95 (China), DS/DL2 (Japan), and KF94 (South Korea).

Existing N95 masks are comprised of multiple layers of materials, the most important of which is the layer produced by the meltblown process. This meltblown fabric (100 to 1000  $\mu\text{m}$  thick) is made from polypropylene microfibers, with diameters in the range of 2-10  $\mu\text{m}$ . Meltblown fibers can cross

each other to form a three-dimensional porous structure (Fig. 1), with porosity up to ~90%. Thus, these fabrics have a relatively low pressure drop and can hold a large quantity of particulate matter. Due to the large fiber diameters compared with small and harmful particles and large pores between fibers, the fibers themselves are not sufficient. Therefore, meltblown fibers are typically electrostatically charged to increase the interaction with the particles, resulting in a much higher filtration efficiency without increasing the air resistance.



**Figure 1.** Scanning electron microscopy (SEM) image of meltblown microfiber fabric.

The current COVID-19 pandemic has led to a significant shortage of N95 facial masks, especially for healthcare individuals. **The primary question to address is whether N95 facial masks can be disinfected in such a way that allows for reuse without reducing the filtration efficiency.** We used five common disinfection methods on a meltblown layer, which determines the filtration efficiency in N95 masks: 1) hot air (oven), 2) UV light, 3) solution of alcohol, 4) household chlorine-based bleach, 5) steam from hot water.

We measured the two most important parameters: the particle filtration efficiency and air pressure drop, before and after disinfection treatments. The pressure drop reflects the air resistance, and a significant change would reflect that the three-dimensional porosity of the filtration material has changed. For example, if the air pressure drop is reduced significantly, it may imply that the meltblown fibers have been damaged. Meanwhile, a reduction in filtration efficiency may suggest a reduction in the static charge on the fibers and/or damage to fabric.

*Please note that this study does not provide the results to evaluate whether these methods are effective towards disinfection of COVID-19. While these methods may have been used for the disinfection of other viruses, we have not evaluated this for COVID-19 specifically. The key information we provide is whether the efficiency of N95 filtration materials is changed after disinfection.*

In the previous Stanford Medicine COVID-19 report compiled by Amy Price, DPhil (Oxon) and Larry Chu, MD, we have shared our results based on a one-time disinfection treatment (Table 1). **We concluded that 75% alcohol solution and chlorine-based solutions were detrimental to the static charge in our meltblown fabric, and resulted in reduced efficiency. In this report,**

**we focused on multiple treatment cycles of three promising methods: 1) hot air (75 °C, 30 min/cycle), 2) UV light (254 nm, 30 min/cycle), 3) steam from hot water (10 min/cycle).**

Note: Steam may not be an ideal choice as polypropylene, the component of meltblown fibers, is hydrophobic (repelling water). Using enough steam can saturate the fibers and the condensation of water may reduce the fibers' static charge. Further repeated disinfections may compromise the filtration ability. UV light will lose its effectiveness if filters are stacked such that the light cannot penetrate into all of the mask material. Further studies are underway to better define the temperature limits and treatment times of all recommended disinfection treatments.

**Table 1.** One-time disinfection treatment on a N95-level meltblown fabric

Samples	Meltblown		Static-charged cotton		E. Coli. disinfection (%)
	Filtration efficiency (%)	Pressure drop (Pa)	Filtration efficiency (%)	Pressure drop (Pa)	
Hot air (oven) 70 °C, 30 min	96.60	8.00	70.16	4.67	>99
UV (sterilizing cabinet) 30 min	95.50	7.00	77.72	6.00	>99
75% alcohol solution soaking and drying	56.33	7.67	29.24	5.33	>99
Chlorine-based solution 5 min	73.11	9.00	57.33	7.00	>99
Steam (hot water vapor) 10 min	94.74	8.00	77.65	7.00	>99
Initial samples before treatment	96.76	8.33	78.01	5.33	

## 2. Experimental procedures

### 2.1 Disinfection method 1: Hot air (75 °C)

Note: we changed the temperature from 70 °C in the previous Stanford Medicine report to 75 °C in this report due the wide availability of 75 °C blanket warming oven at hospitals, as provided by Dr. Larry Chu (Stanford Medicine).

- 1) Prepare 15 pieces of meltblown fabric (15 cm × 15 cm, each).
- 2) Test 3 samples for filtration efficiency and pressure drop via TSI 8130A.
- 3) Preheat the oven (Figure 2) to 75 °C.
- 4) Put the remaining (12) samples into the oven.

- 5) After 30 minutes of heating, take out all the samples and cool at room temperature for 10 minutes.
- 6) Repeat Step 5 for a total of 20 total cycles.
  - a. After every 5 cycles, pick 3 samples to test as given in Step 2.



**Figure 2.** AI 14 Shelf Max 5 Cu Ft 480°F 5-Sided Heating Vacuum Oven, Across International LLC.

## 2.2 Disinfection method 2: UV

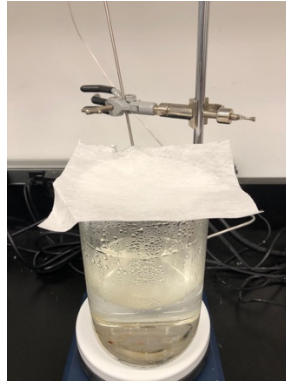
- 1) Prepare 3 pieces of meltblown fabric (15 cm × 15 cm, each).
- 2) Place samples into a UV sterilizer (Figure 3, 254 nm wavelength, 8 W UV light bulb).
- 3) Irradiate under UV light for 30 minutes.
- 4) Take out the samples and let stand under ambient conditions for 10 minutes.
- 5) Repeat Steps 3-4, for a total of 10 cycles.
- 6) Test the filtration efficiency and pressure drop via TSI 8130A.



**Figure 3.** Sterilizer Cabinet With UV, CHS-208A, 110V/60 Hz, 254 nm

## 2.3 Disinfection method 3: Steam

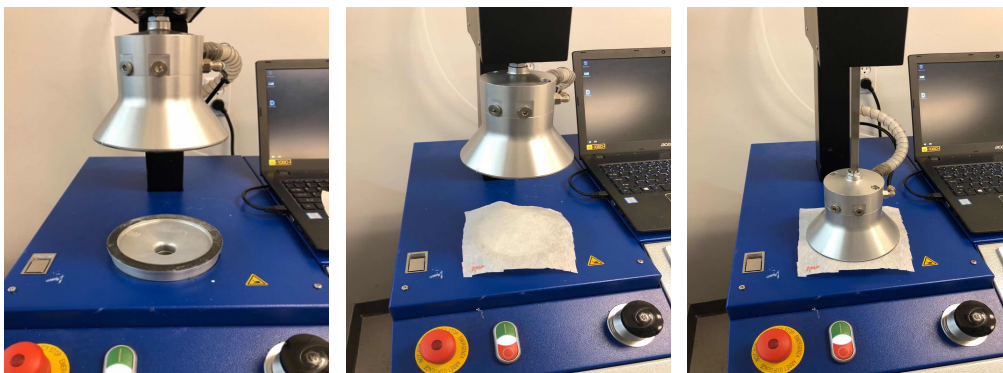
- 1) Prepare 12 pieces of meltblown fabric (15 cm × 15 cm, each).
- 2) Prepare a beaker with clean water and heat on a hot plate to a boil.
- 3) Place the 3 samples stacked on the beaker and heat them via boiling water vapor for 10 minutes (Figure 4).
- 4) Take the samples off and cool at room temperature, making sure the samples are dry.
- 5) Test the filtration efficiency and pressure drop via TSI 8130A (cycle 1).
- 6) Separately, repeat steps 3-4 with the remaining meltblown fabrics, testing at cycles 3, 5, and 10 (each a set of 3 meltblowns).



**Figure 4.** hot water steam disinfection

## 2.4 Air filtration efficiency measurement

We used the standard filter testing TSI 8130A to measure the air filtration efficiency and pressure drop under the flow rate of 32 L/min. The experimental apparatus is show in Figure 5.



**Figure 5.** TSI 8130A for filtration efficiency and pressure drop measurement.

## 3. Results and discussion

The efficiency of the initial meltblown fabric from five samples is in the range of 95.77 to 99.02% with an average at 97.44%. The air pressure drop is from 8-11 Pa, with the average at 8.8 Pa.

**Table 2.** Initial meltblown fabric without any disinfection treatment

#	Original	
	Efficiency (%)	Pressure Drop (Pa)
1	97.38	8
2	98.67	9
3	99.02	11
4	96.37	7
5	95.77	9
Average	97.44 ± 1.41	8.8 ± 1.5

**Disinfection method 1: Hot air (75 °C)**

Compared to the initial 97.44% filtration efficiency, the efficiency after 15 cycles of hot air treatment shows no change (97.51%). This holds true after 20 cycles as well, with nearly no change (95.96%). The pressure drop is also nearly constant. This data suggests that 75 °C hot air does not cause the static charge to decay and does not change the three-dimensional structure of filter.

**Table 3.** Hot air (75 °C) disinfection

Cycle	Hot Air (30 min, 75 °C)	
	Efficiency (%)	Pressure Drop (Pa)
5	96.86	7
	96.02	6
	96.21	7
Average	96.36 ± 0.44	6.7 ± 0.6
10	96.85	7
	97.48	8
	97.41	9
Average	97.25 ± 0.34	8.0 ± 1.0
15	97.47	8
	97.94	11
	97.12	8
Average	97.51 ± 0.41	9.0 ± 1.7
20	95.74	8
	95.7	8
	96.44	9
Average	95.96 ± 0.42	8.3 ± 0.6

### Disinfection method 2: UV

After 10 cycles of UV treatment, the meltblown filtration efficiency and pressure drop remained constant. Despite the fact that 254 nm UV light can break the chemical bonds of polypropylene, the UV dosage here does not cause any noticeable damage to the meltblown.

**Table 4.** UV disinfection

Cycle	UV light (30 min)	
10	96.01	10
	96.73	7
	97.60	10
Average	96.78 ± 0.80	9.0 ± 1.7

### Disinfection method 3: Steam

After the first 3 cycles, the steam does not seem to change the filtration efficiency. However, after 5 cycles, the filtration efficiency sees an appreciable drop from ~97% to ~85%. After 10 cycles, the efficiency significantly degrades ~80%. The air pressure drop does not significantly change, suggesting that the three-dimensional structure of the meltblown fabric does not change. This implies it is most likely the steam degrading the static charge of the fiber.

**Table 5.** Steam disinfection

Cycle	Steam (10 min)	
1	97.49	10
	98.19	10
	98.23	10
Average	97.97 ± 0.41	10.0 ± 0.0
3	95.19	9
	96.91	8
	97.14	10
Average	96.41 ± 1.07	9.0 ± 1.0
5	83.94	8
	85.14	6
	86.03	8
Average	85.04 ± 1.05	7.3 ± 1.2
10	80.47	7
	77.77	9

	83.71	9
Average	80.65 ± 2.97	8.3 ± 1.2

#### 4. Conclusion and Additional Notes

**From our results, there are two disinfection methods which do not reduce the filtration efficiency of the meltblown layer after an appreciable number of treatment cycles. We found:**

**Method 1: 75 °C Hot air (30 min) for 20 cycles**

**Method 2: UV (254 nm, 8 W, 30 min) for 10 cycles.**

**Regarding treatment with steam, we advise caution. For 3 treatment cycles or less, we found the filtration efficiency can be maintained at >95%. However, after 5 cycles the efficiency drops to ~85%, and 10 cycles will drop the efficiency to ~80%.**

#### **Additional notes:**

- 1) Based on the SARS coronavirus study, 75 °C for 30 min is sufficient for disinfection (<https://www.ncbi.nlm.nih.gov/pubmed/14631830>)
- 2) UV treatments in our study did not alter the filtration efficiency at 10 cycles. However, we are concerned about the limited penetration depth of UV light. This may limit its virus disinfection capability for particles deep within the filter. This requires additional study.
- 3) Our study is based on one type of meltblown fabric for N95 masks. We have not broadly tested different meltblowns.
- 4) For the 75 °C hot air (30 min) treatment, we simultaneously tested a whole N95 mask. After 20 cycles, we found that the N95 mask did not have any deformations. The elasticity of the ear/face straps were not degraded and were suitable for use.