香港科技大學
THE HONG KONG
UNIVERSITY OF SCIENCE
AND TECHNOLOGY

Possibility of extending and limited reuse of surgical mask during extreme shortage condition in low risk areas

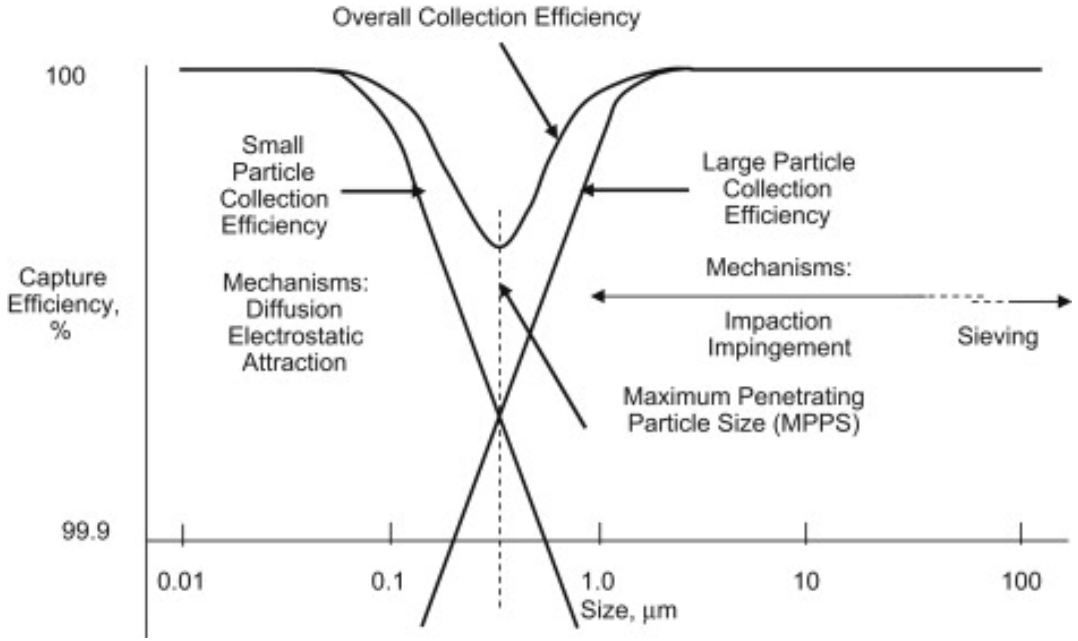
by Prof. Joseph KWAN

Aim

- To explore the possibility of limited reuse of surgical mask in **low risk areas** (eg: non-clinical settings) amid extreme shortage in supply.
- To find practical sterilization methods that deal the **least damage** to surgical masks based on lab test results.
- While it is **NOT** our aim to promote reuse of disposable surgical masks, we wish to verify the many hypothesises and misconceptions about the reuse of masks with scientific methodologies, so as to provide people with an alternative.

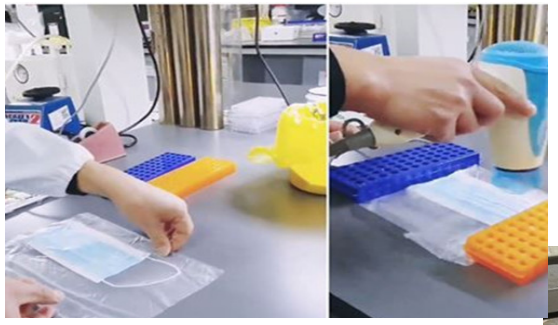
Background information

- Surgical masks are designed for one time use.
- Surgical masks are not respirators, so they do not require a fit-test prior to first-time use, and air would leak around their edges.
- Capture efficiency is the lowest at 0.3 micron, therefore our filtration tests were conducted for particles between 0.1 – 1 micron.



Current situation

- Although surgical mask was primarily designed for single use, the general public is using different methods to reuse surgical masks as supply is limited.
- These methods include disinfecting the masks through steaming, boiling or dry heating and/or with agents such as ethanol, detergent, bleach etc.



Disinfecting methods

Treatment Method	Treatment time
Submersion in 75% Ethanol (followed by natural drying)	5 mins
Spray 75% Ethanol (followed by natural drying)	-
Submersion in 95% Ethanol (followed by natural drying)	5 mins
Submersion in detergent water (followed by rinsing and natural drying)	30 mins
Submersion in 1:99 bleach (followed by rinsing and natural drying)	30 mins
Submersion in Betadine Hand wash (followed by rinsing and natural drying)	10 mins
Treatment with chlorine dioxide gas	10 mins
Boiling at 100 °C	10 mins
Steaming at 100 °C	10 mins
Autoclave at 121 °C	20 mins
Baking at 100 °C	15 mins
UVC irradiation (450 μW/cm^2)	30 mins

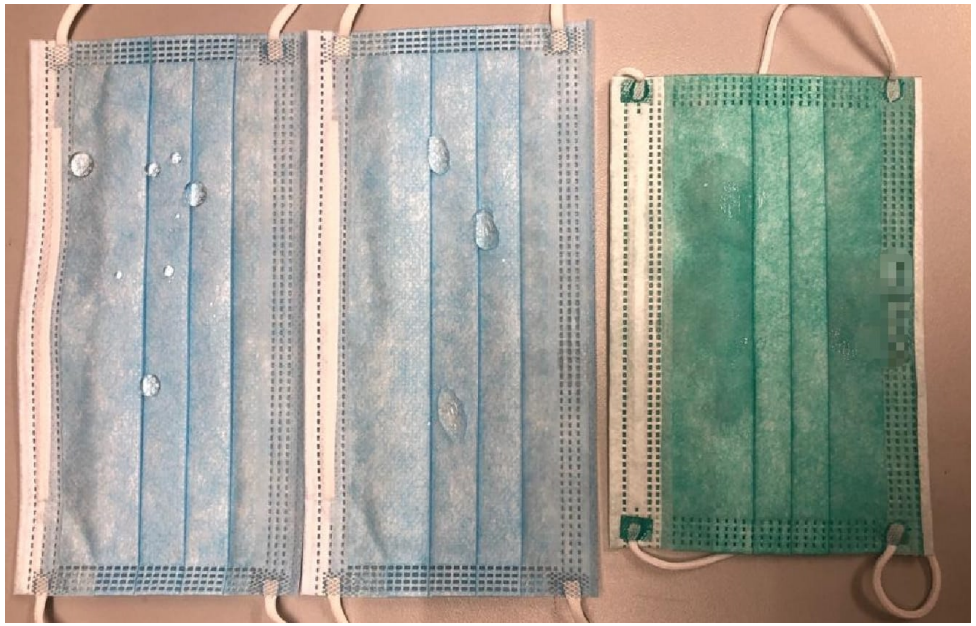
Factors to consider in this experiment

1. Liquid-repelling power of the masks' outer layer
2. Particle filtration efficiency of the masks' filter layer
3. Structural change of the masks' filter layer

Testing methods

1) Liquid-repelling Layer Test

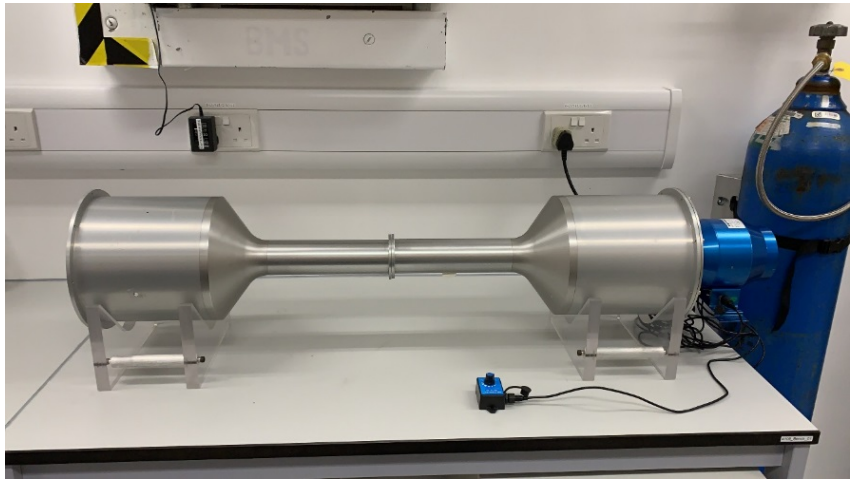
- Water are sprayed onto the surface and hold for 5 mins before softly sweeping the droplets.
- If water stays on the mask's surface as a droplet, liquid-repelling layer is considered not damaged.
- If the water droplet is being absorbed or partially absorbed by the masks, liquid-repelling layer is considered damaged.

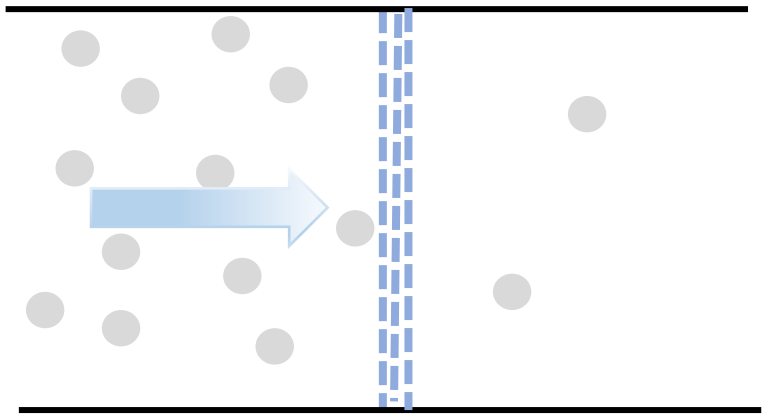


Testing methods

2) Particle Filtration Efficiency Test (顆粒過濾效率測試)

- The test was used to determine the material performance based on the filtration efficiency of non-viable particles. Sodium chloride particles were used to simulate sub-micron exhaled droplets generated from coughing and talking.
- Testing particles: 0.1-1 μm Sodium chloride
  Temperature: 20 ˚C
  Relative Humidity: 32.1%





Schematic diagram of PFE

Machine list: Particle generator (TSI 8026), Aerosol Monitor (TSI Dusttrak II), Anemometer (TSI VelociCalc 9515), Laminar and directional flow tubing system (flow system)

Testing methods

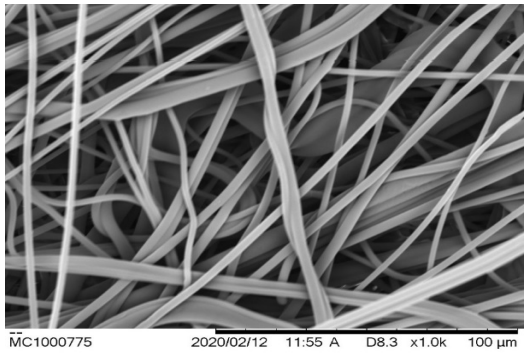
3) Scanning Electron Microscopy

(掃描電子顯微鏡)

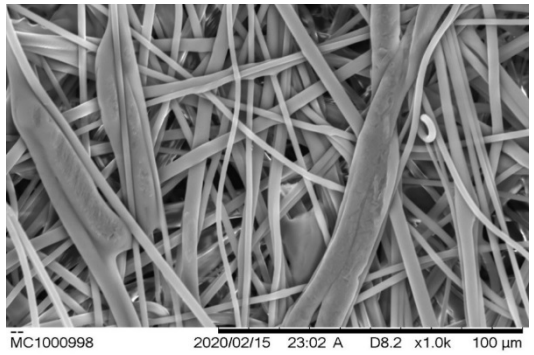
- The middle (filter) layer is put under electronic microscope for observation of any structural changes
- Things to observe: uniformity deformation, entanglement or cracks of fibre

SEM image – different treatment methods

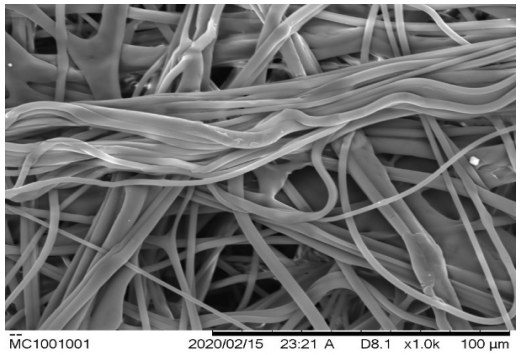
Treatments with solvents (wet) at 1000x magnification



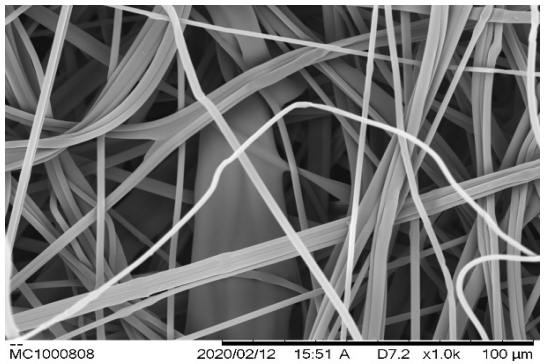
New mask



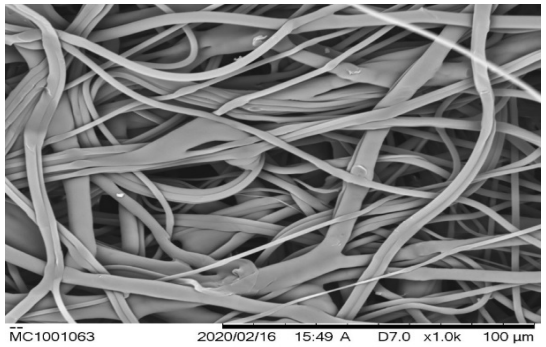
75% Ethanol 5 mins



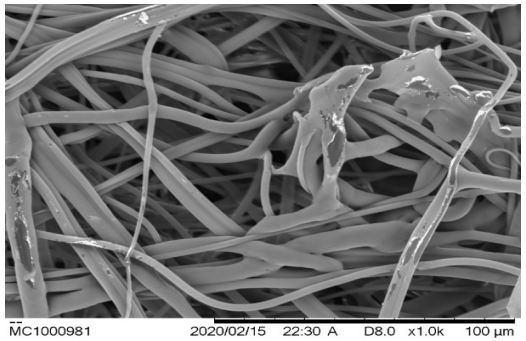
95% Ethanol 5 mins



Detergent water 30 mins

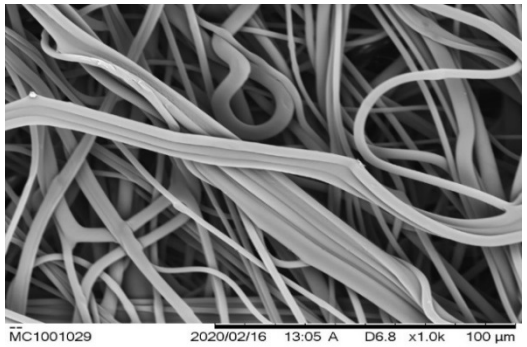


Boiling 30 mins



Steaming 30 mins

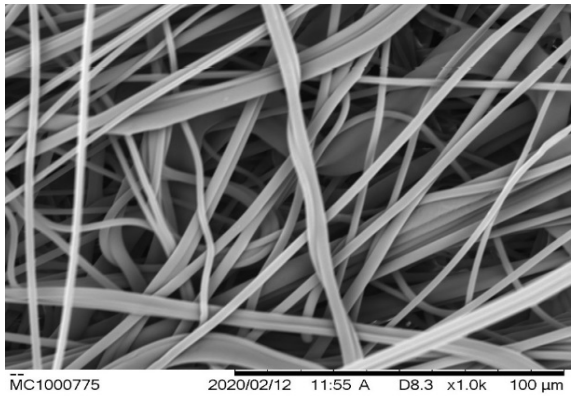
Autoclave 121°C, 20 mins



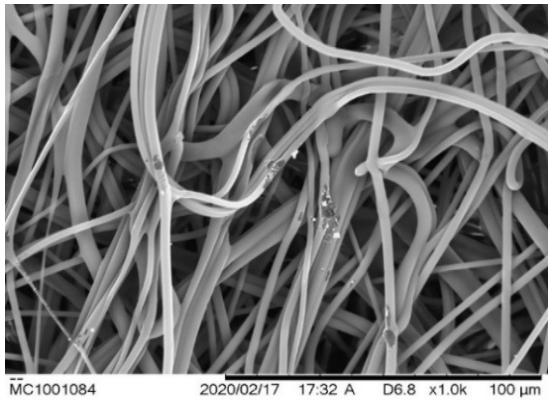
1:99 Bleach 30 mins

SEM image – different treatment methods

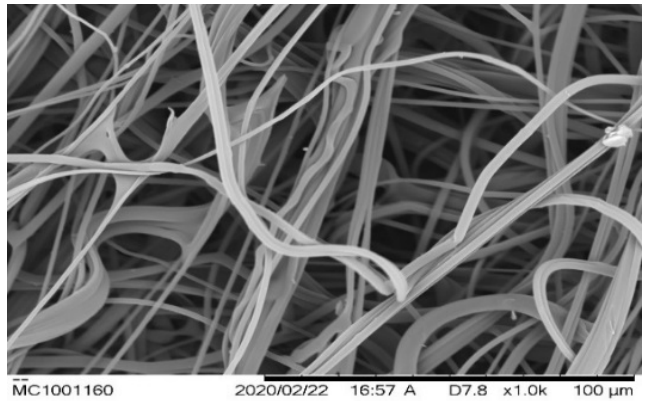
Treatments without solvents (dry) at 1000x magnification



New mask

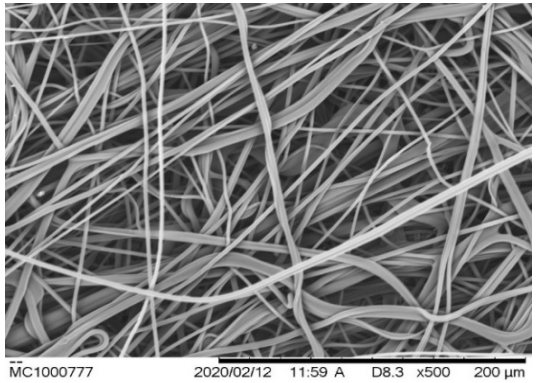


UVC 30 mins

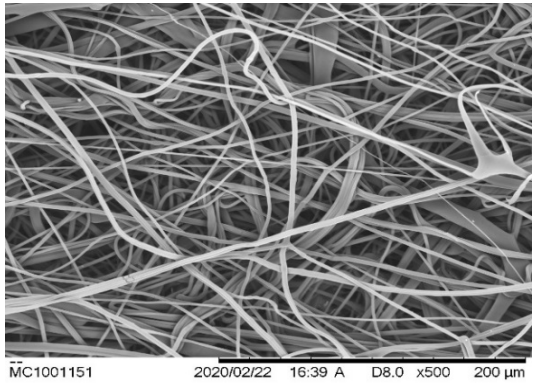


Baking 100 °C, 30 mins

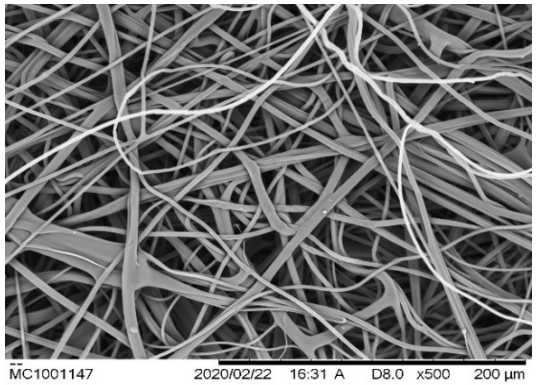
SEM image – used mask



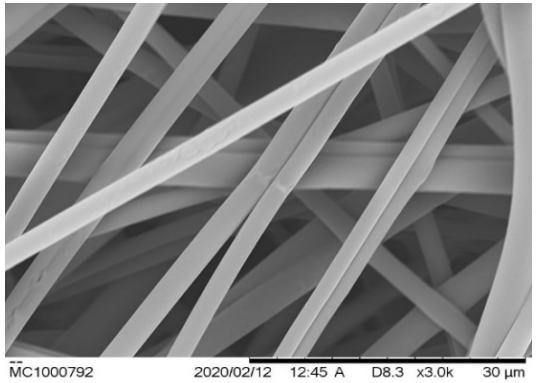
New mask (500x)



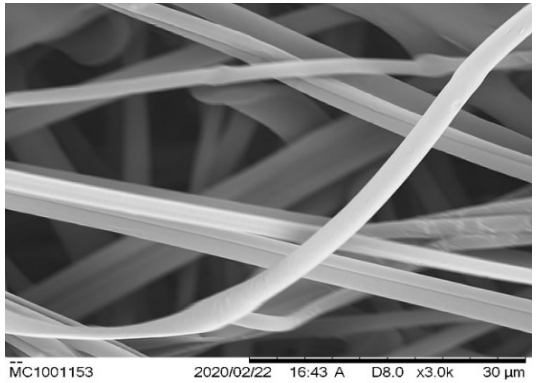
Used (500x)



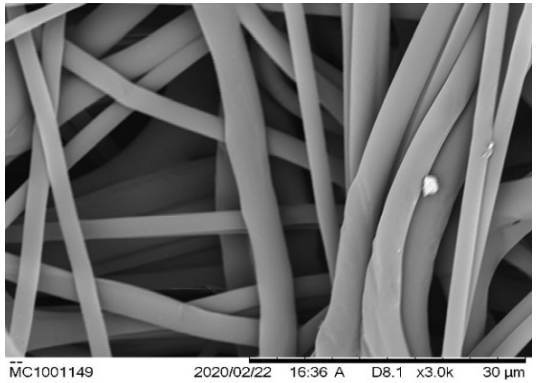
Used, Baking (100℃, 15 min) (500x)



New mask (3000x)



Used (3000x)



Used, Baking (100℃, 15 min) (3000x)

Findings

Treatment Method	Treatment time & condition	*S.aureus* reduction	% drop in Particle Filtration Efficiency * (0.1µm - 1 µm)	Liquid-Repelling layer
75% ethanol	5 mins	99.99%	26.4%	Damaged
95% ethanol	5 mins	99.99%	25.5%	Damaged
Boiling	10 mins	99.99%	3.8%	Damaged
Steaming	10 mins	99.99%	0.8%	Damaged
Autoclave	121℃, 20 mins	99.99%	3.1%	Damaged
Baking	100℃, 15 mins	99.99%	1.3%	No Observable Effect
Detergent water	30 mins	50.86%	23.7%	Damaged
UV irradiation	30 mins	99.99%	0.4%	No Observable Effect
1:99 bleach	30 mins	99.99%	0.3%	Damaged
Spray 75% ethanol	10 mins	35.17%	-	Damaged
Betadine hand wash	10 mins	99.99%	60.3%	Damaged
Chlorine Dioxide	10 mins	99.99%	2.3%	Damaged
Used 1-day Mask	-	-	1.3%	No Observable Effect
Used Mask+Baking(100℃)	15 mins	99.99%	2.6%	No Observable Effect
Used Mask+UV	15 mins	99.99%	2.4%	No Observable Effect

The mask used in above treatments is Medicom SafeMask® Premier Earloop, ASTM Level 1

* Particle Filtration Efficiency is with respect to the untreated control

Masks samples acquired from the market

Sample	Layers	Claim	Filtration Efficiency (0.1µm - 1 µm)	Face Velocity + (cm/s)
Sample 1	3	ASTM Level 2	99.7%	4
Sample 2	3	ASTM Level 1	98.8%	13
Sample 3	3	PFE > 95%, BFE > 95%	98.1%	14
Sample 4	3	ASTM Level 1	97.9%	14
Sample 5	3	PFE > 95%	95.7%	14
Sample 6	3		86.9%	27
Sample 7	3		84.9%	14
Sample 8	3		63.5%	8
Sample 9	3		58.0%	11
Sample 10	4		54.5%	14
Sample 11	3		49.7%	16
Sample 12	3		47.2%	13
Sample 13	3	PFE > 99%, BFE > 99%	39.3%	16
Sample 14	3		30.8%	19
Sample 15	3	PFE > 95%	17.0%	23
Sample 16	3		13.9%	105
Sample 17	3		1.8%	61

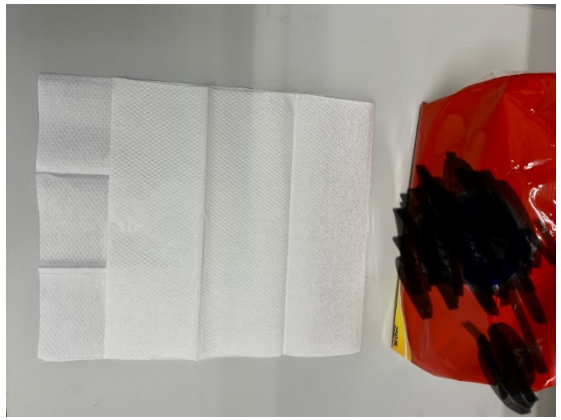
Despite the extreme shortage, it is important to acquire surgical masks with certification or buy from reputable retailers

+ Breathability level. 14 cm/s is the reference velocity

Performance of different ingredients for DIY masks

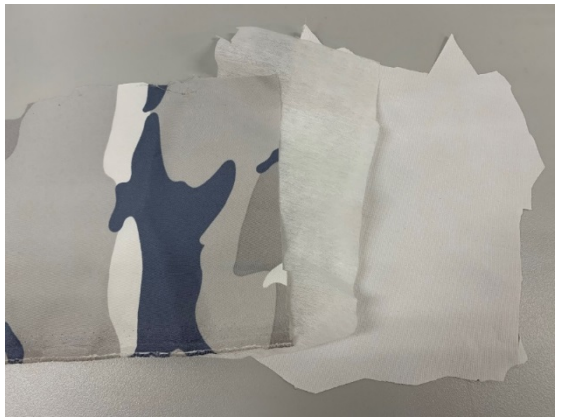
Sample	Layers	Filtration Efficiency (0.1µm - 1 µm)	Face Velocity + (cm/s)	Remarks
Kitchen paper	2	99.5%	1	
Tissue paper	4	71.6%	6	
DIY mask	3	99.9%	<1	With waterproof cloth
Disposable wiper	2	46.2%	2	

+ Breathability level. 14 cm/s is the reference velocity

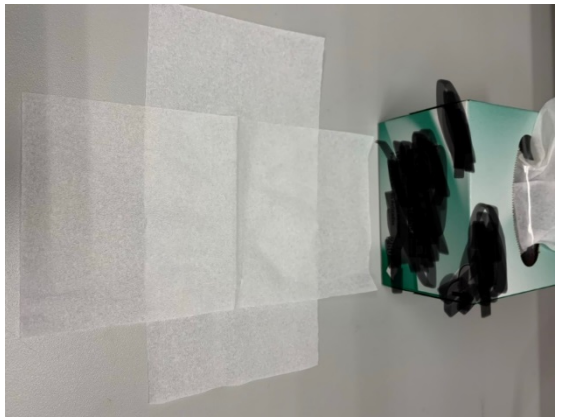


Kitchen paper

Tissue paper



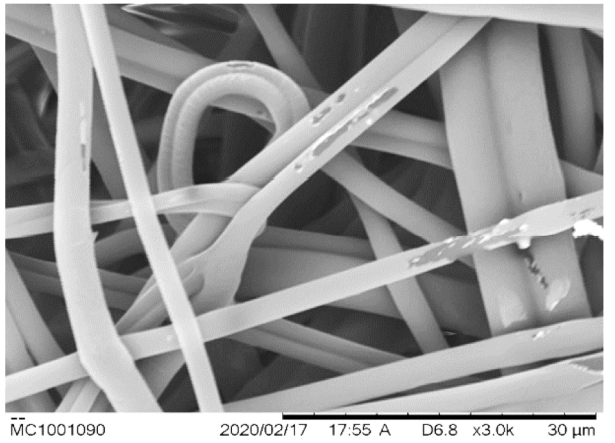
DIY mask



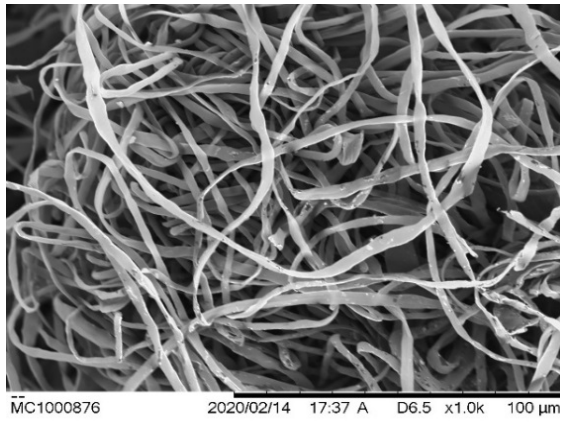
Disposable wiper

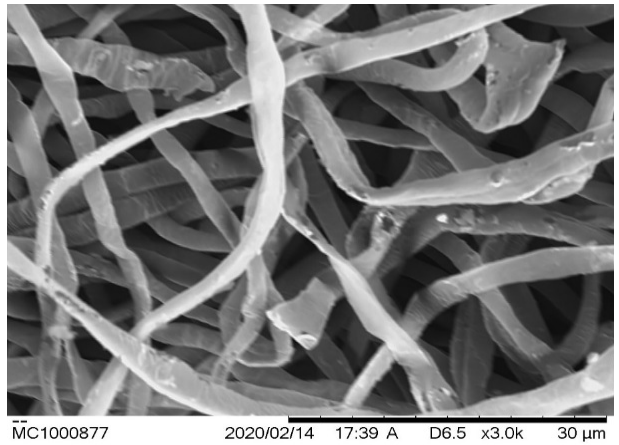
Important messages from experiments

- Any treatment methods that include the use of solvent such as water, detergent, ethanol or bleach solution will alter the surface property of filtering layer.
- Solvent will also alter the liquid-repelling property of the outermost liquid-repelling layer;
- Non-contact UV treatment causes limited damages to filtration and waterproof abilities but **implementation is difficult.**
- Excessive force applied to the mask (such as rubbing) will severely damage the micro-structure of the filter.



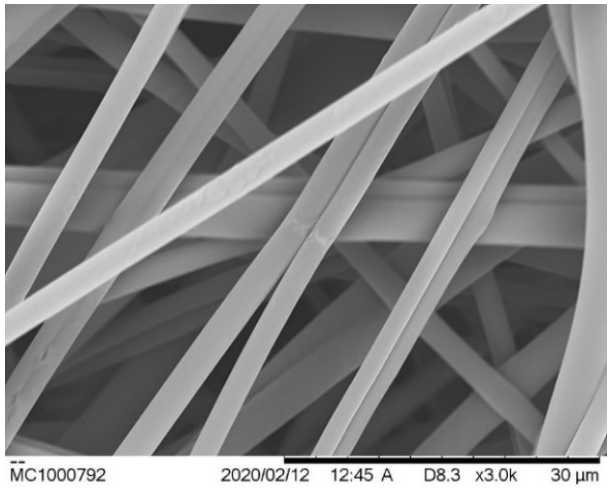
After UVC treatment



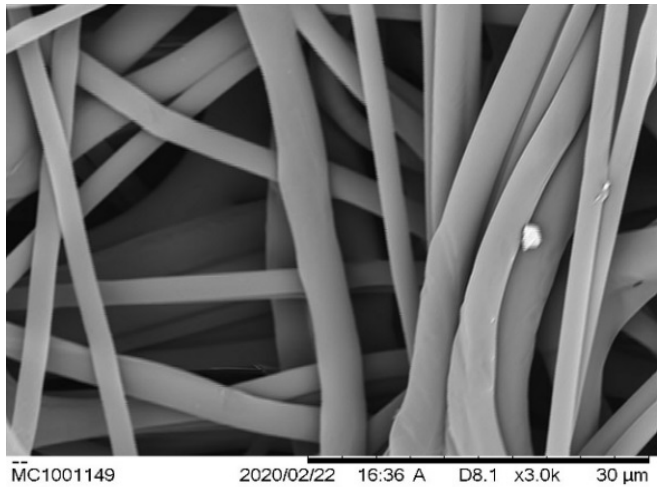


After rubbing

Dry thermal sterilization



Untreated



Baking at 100°C

Dry thermal treatment deals least damage to filter material and particle filtration efficiency.

Possible and implementable ways of thermal treatment

- Boil/steam in a tight-sealed container
- Oven bake in a sealed container

Dry thermal sterilization

1

1. Carefully take off your used masks and put them between kitchen towels.
2. Put inside a heat tolerant container.
3. Wear heat resistant gloves when necessary.

or

2

Baking at 100°C for 15 mins
(need not tightly-sealed)

2

Steaming at 100°C for 15 mins
(**tightly-sealed**)

3

Clean your hands

4

Make sure that no steam and liquid will get into the container/contact with the mask when you remove it from the heater or the container.

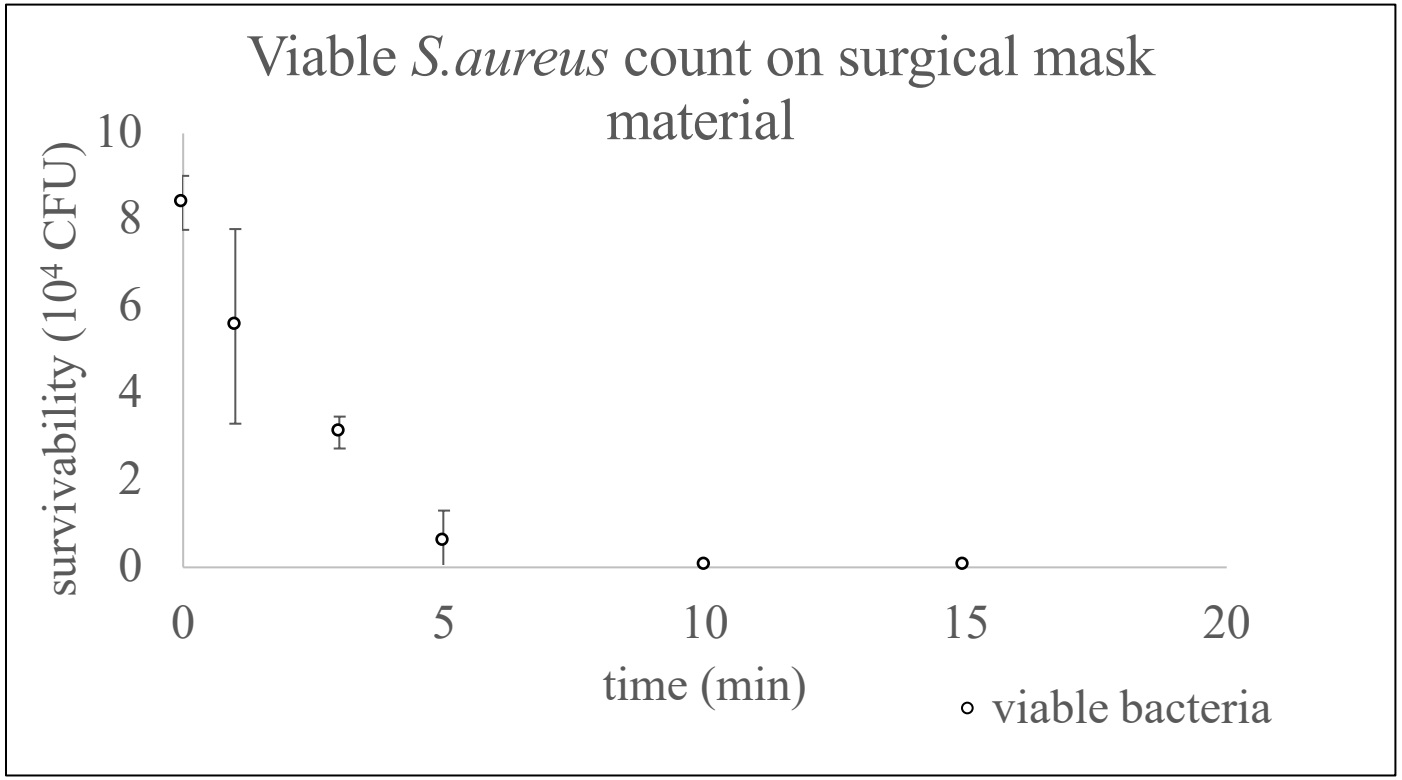
- 99.99% reduction of *S. aureus* in 15 mins
- < 3.5% reduction in particle filtration efficiency in our samples.
  (total 6 models of masks are tested)

* Let the ramping finish before putting in the container for heat treatment.

Thermal treatment

- Deliberately contaminate mask material with 10^4 CFU *S.aureus* (with detergent) as a simulation to high load of contaminated droplets

- Mask material was placed in a concealed container for thermal treatment at 100 °C.



Take home message

- It is **NOT** recommended to reuse a surgical mask as disinfection will always cause some damages to the liquid-repelling and filtering layers.
- When there are no alternatives, disinfecting a surgical mask should be carried out with proper steps under strict conditions so that the least damage is caused.

Take home message

- **Cleaning your hands is equally important**. Clean them with soap and water properly before and after putting on/ taking off a mask. Hand wash is the most important and least expensive measure to reduce the risk of transmission of microorganisms. If soap and water are not available, alcohol-based hand sanitizer can be an alternative.
- Purchase masks only from reputable brands and sources.

Q&A