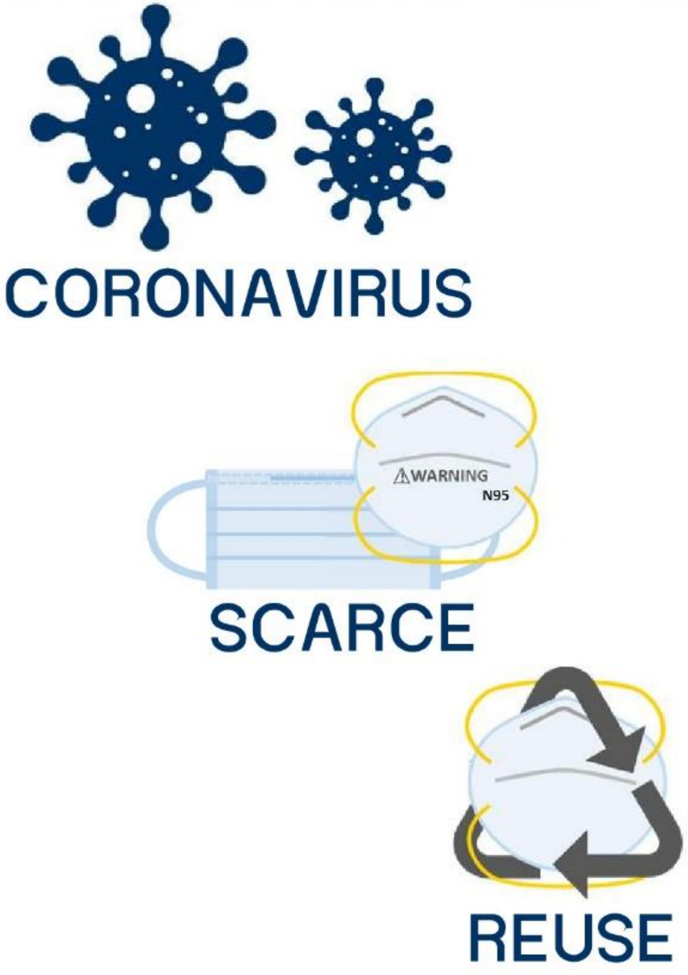
Disinfecting the N95 mask with UV and Ozone

In case of needing to use repeatedly



Background: Due to the coronavirus – 2019 outbreak, N95 and surgical masks have become scarce. Reuse of N95 masks after disinfection may be unavoidable for healthcare workers. However, water, alcohol, and solution-based methods have shown to dramatically damage the physical properties of the masks, hence their protective ability is destroyed. UV radiation at an appropriate dosage and ozone treatments with high PPM level are known to be effective in microorganism disinfection. However, the physical properties of the masks after those treatments need to be determined to ensure that the healthcare workers using these reused masks are still protected against dangerous microorganisms.

Cite: Institute of Nanomaterials Research and Innovation for Energy (IN-RIE), Faculty of Sciece, Khon Kaen University, April 2, 2020

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Problem: UV radiations and Ozone treatments may affect microstructure of the filter layers and water resisting ability (called hydrophobicity) of the outer layer of the N95 masks.

Study:

Use Scanning Electron Microscope (SEM) to observe the microstructure and porosity of the filter layers after several rounds of UV radiations and several minutes of ozone treatments.

Use contact angle measurement to observe the hydrophobicity of the outer layer after several rounds of UV radiations and several minutes of ozone treatments.

Note: 120 mJ/cm^2 of UV dose can kill 99.9% Rotaviruses. Other types of virus are much easier to kill (much lower UV Dose of around 5–40 mJ/cm^2 can kill most common viruses.*)

*Ultraviolet Light Disinfection Data Sheet, www.clordisys.com

Experimental procedure

Materials:

11 Brands of N95 masks provided by

Srinakarind Hospital, Khon Kaen (Thailand)

(Note that we are not respondsible for testing fake vs. genuine products and the information is intended for internal use to protect our healthcare staffs only)

Experimental procedure

Ozone treatment

1) 2 min dose
2) 5 min dose
3) 10 min dose
4) 20 min dose
5) 30 min dose

However, due to the toxicity of ozone gas, healthcare workers need to ensure that the masks are properly kept inside a sealed container while exposing them to ozone gas and wait for at least an hour before opening the container. This method is not recommended for the general public.

UV treatment with 120 mJ/cm^2

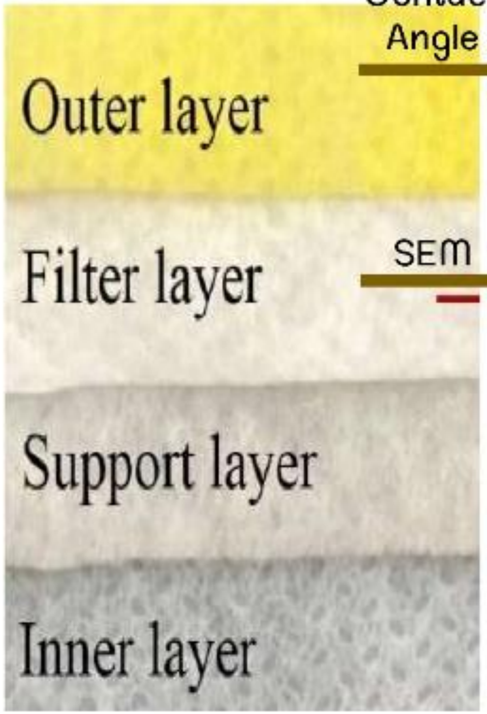
1) 1 round
2) 2 rounds
3) 3 rounds
4) 4 rounds
5) 5 rounds

Temperature is increasing but always below 75 °C for the time/round of 10 mins. UV Dose = 120 mJ/cm^2

(Note that we are not respondsible for testing fake vs. genuine products and the information is intended for internal use to protect our healthcare staff only)

m1 Results

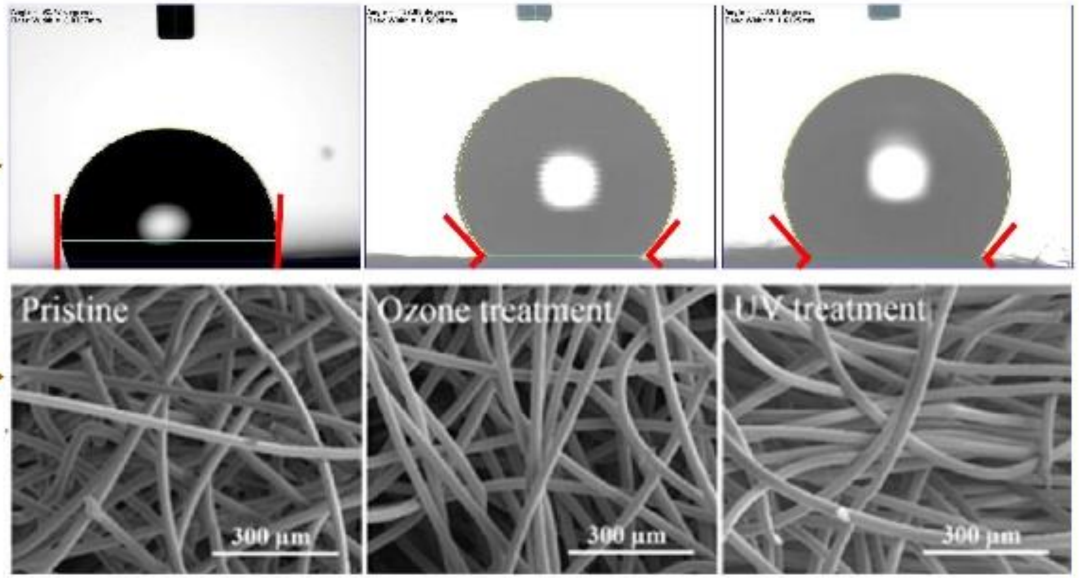
Optical images



Contact Angle

SEM

Pristine | Ozone treatment | UV treatment



(a) (b) (c)

Contact angle becomes slightly higher after UV and ozone treatments. However, the values are all higher than 90 degrees indicating that the masks are water resistance.

SEM images showing fiber structure of pristine (a) Ozone treated for 30 minutes (b) UV radiated at 120 mJ/cm^2 for 5 rounds (c) filter layer. Fiber structure (morphology and size) remain almost unchanged after treatments. Porosity of the filter fibers also does not change significantly.

The masks remain hydrophobic and no obvious physical damages are observed after UV and Ozone treatments.

M 2 Results

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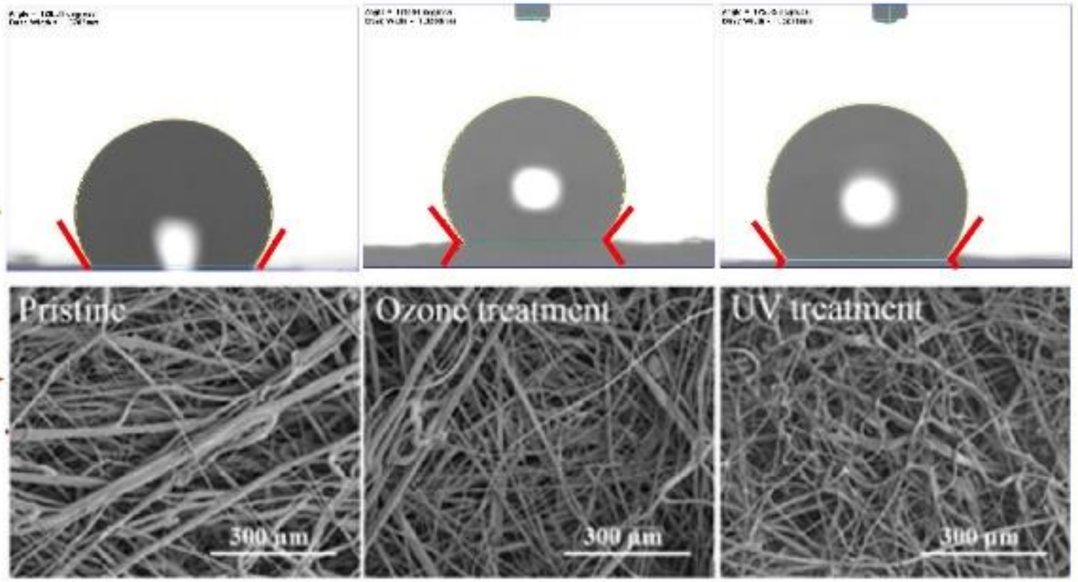
Optical images

Contact Angle

SEM

Pristine	Ozone treatment	UV treatment



(a) (b) (c)

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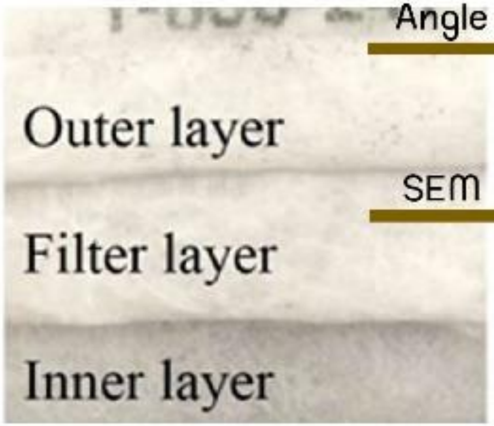
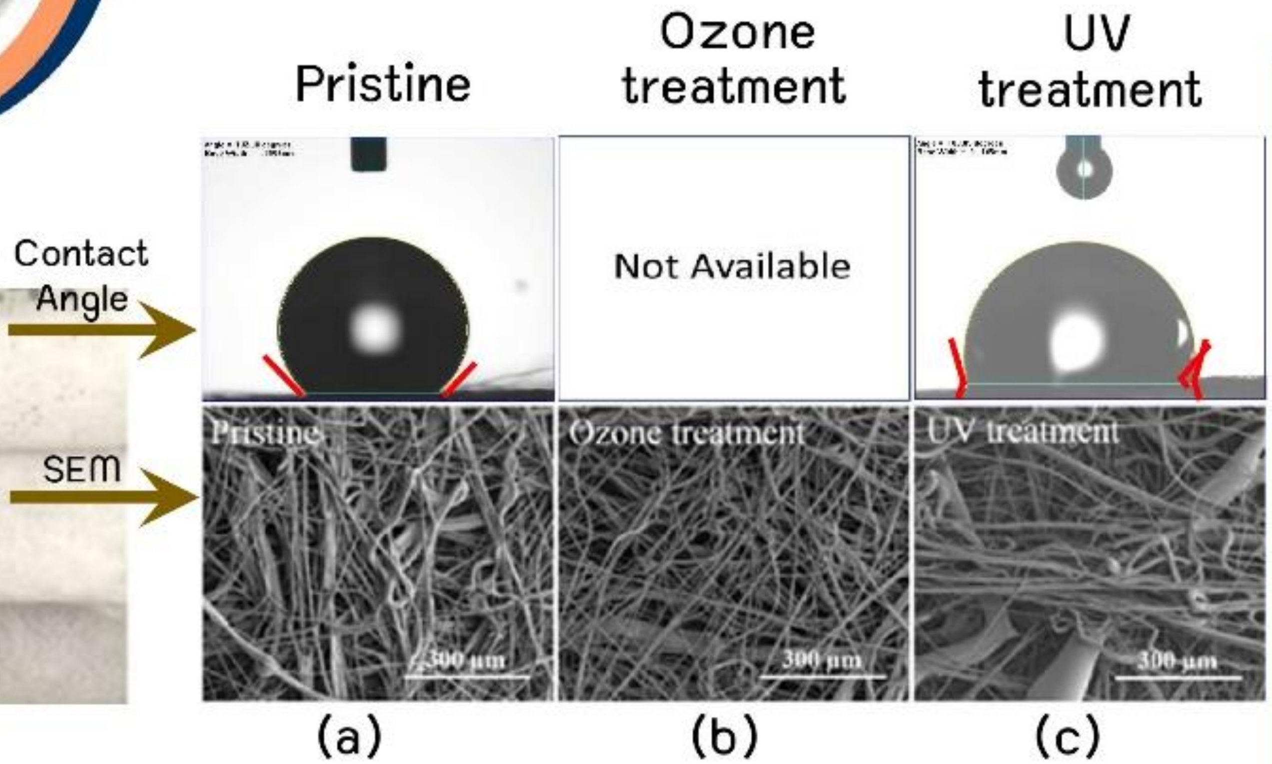
M 3 Results

Optical images





Contact angle becomes slightly lower after UV treatment. However, the values are all higher than 90 degrees indicating that the masks are water resistance.

SEM images showing fiber structure of pristine (a) Ozone treated for 30 minutes (b) UV radiated at 120 mJ/cm^2 for 5 rounds (c) filter layer. Fiber structure (morphology and size) remain almost unchanged after treatments. Porosity of the filter fibers also does not change significantly.

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m 4 Results

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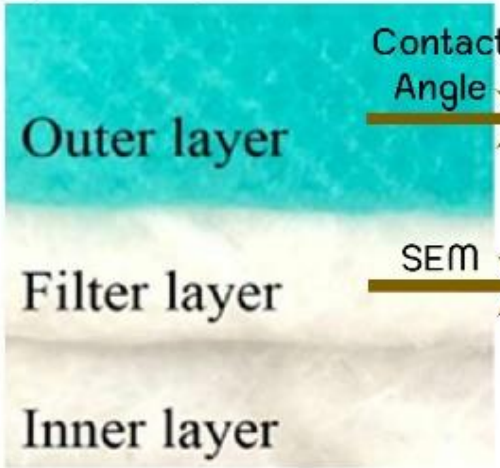
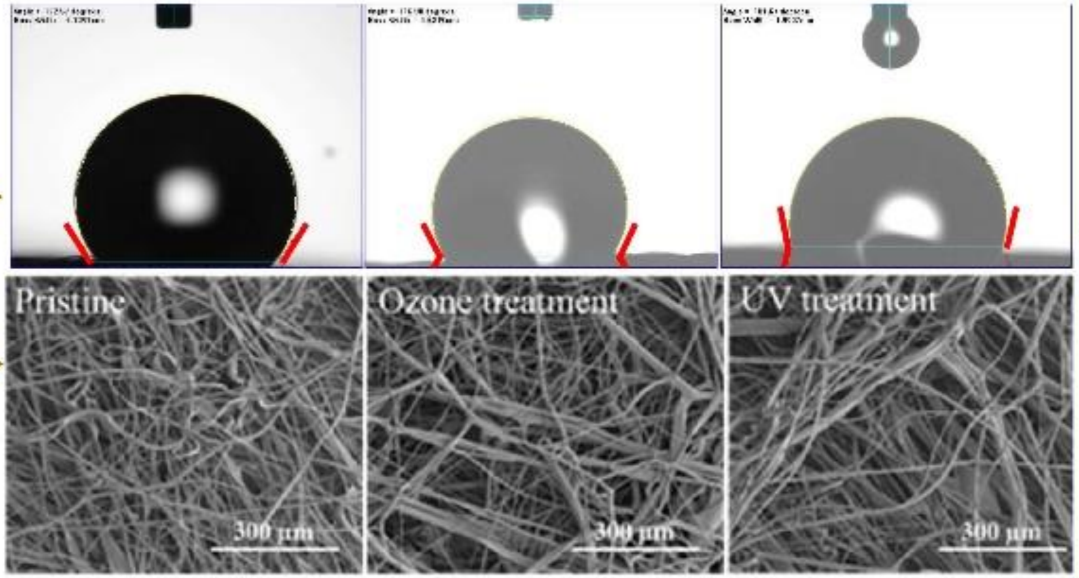
Optical images



Contact Angle

SEM

Pristine | Ozone treatment | UV treatment



(a) (b) (c)

Contact angle becomes slightly lower after UV and higher after ozone treatments. However, the values are all higher than 90 degrees indicating that the masks are water resistance.

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M S Results

Disinfecting the N95 mask

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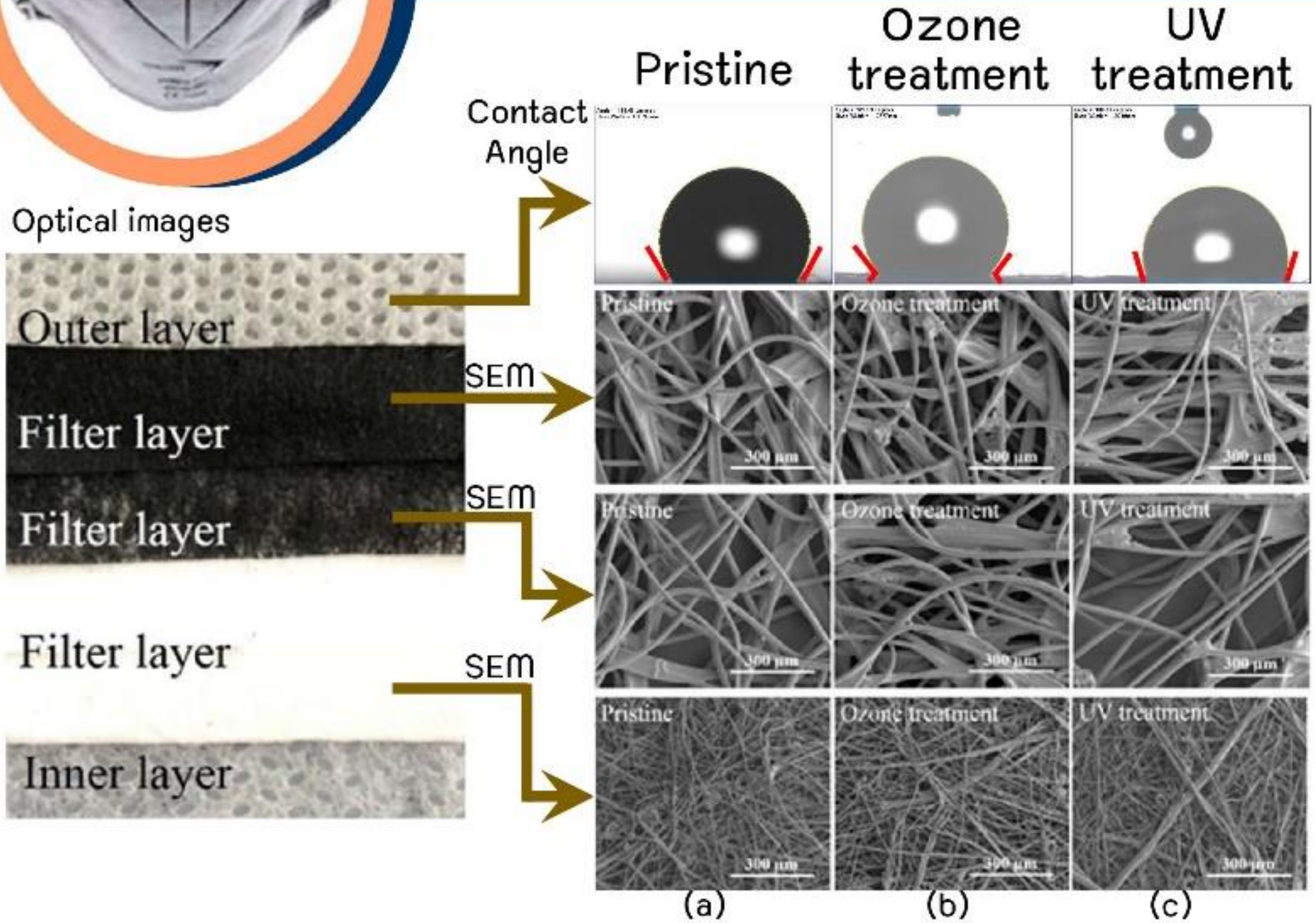

Contact angle becomes slightly lower after UV and higher after ozone treatments. However, the values are all higher than 90 degrees indicating that the masks are water resistance.

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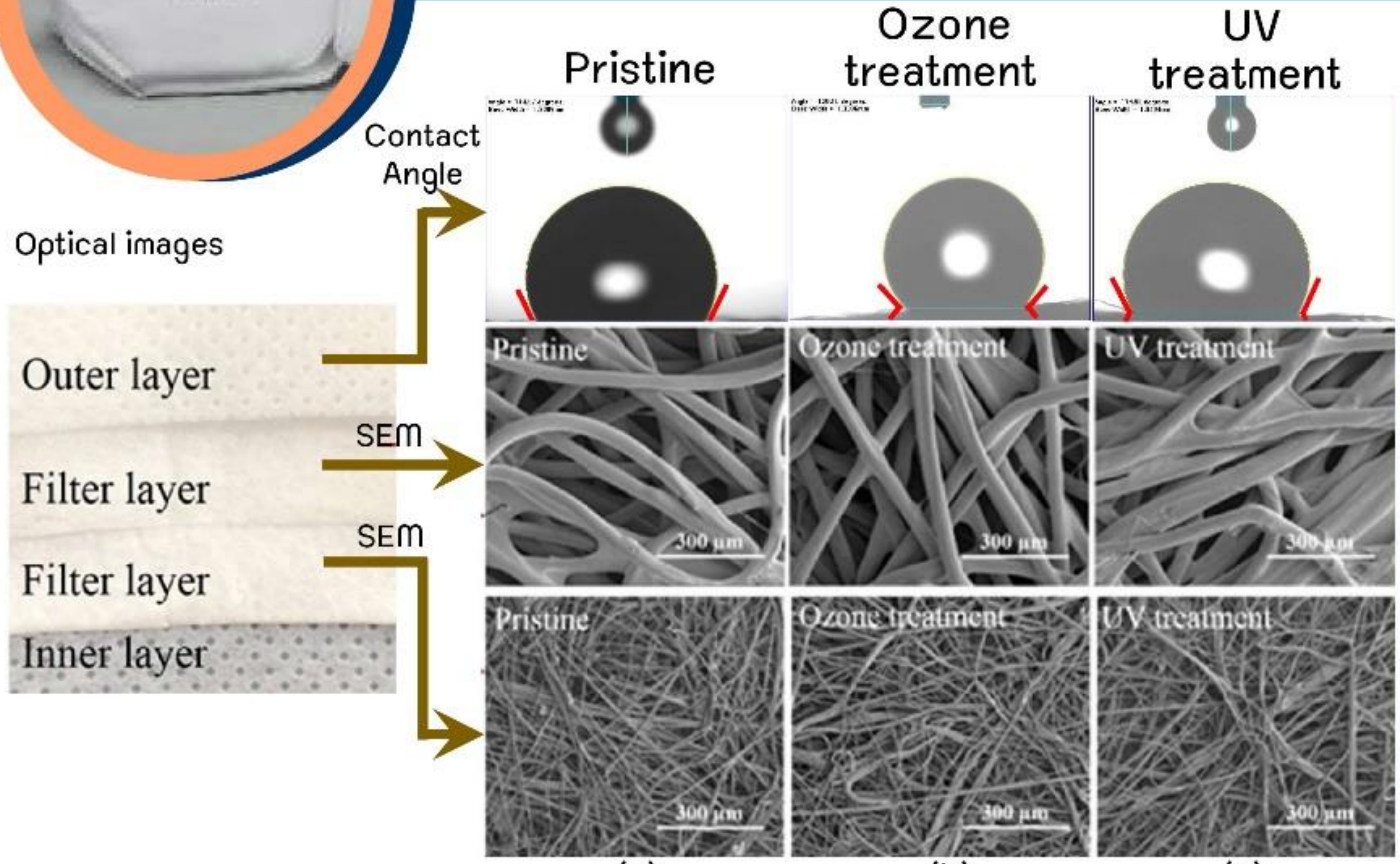
M 6 Results



(a) (b) (c)

Contact angle becomes slightly lower after UV and higher after ozone treatments. However, the values are all higher than 90 degrees indicating that the masks are water resistance.

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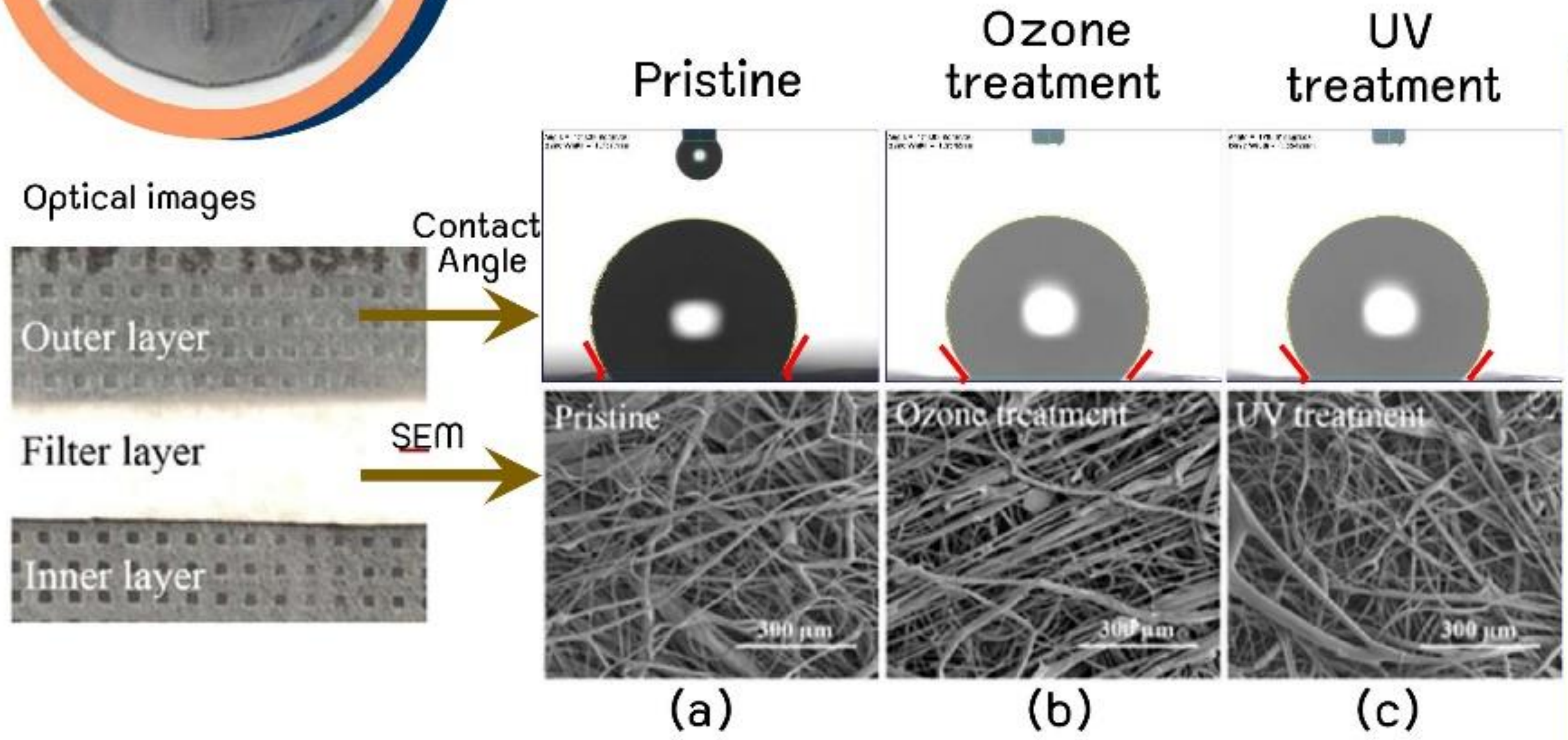
m 7 Results



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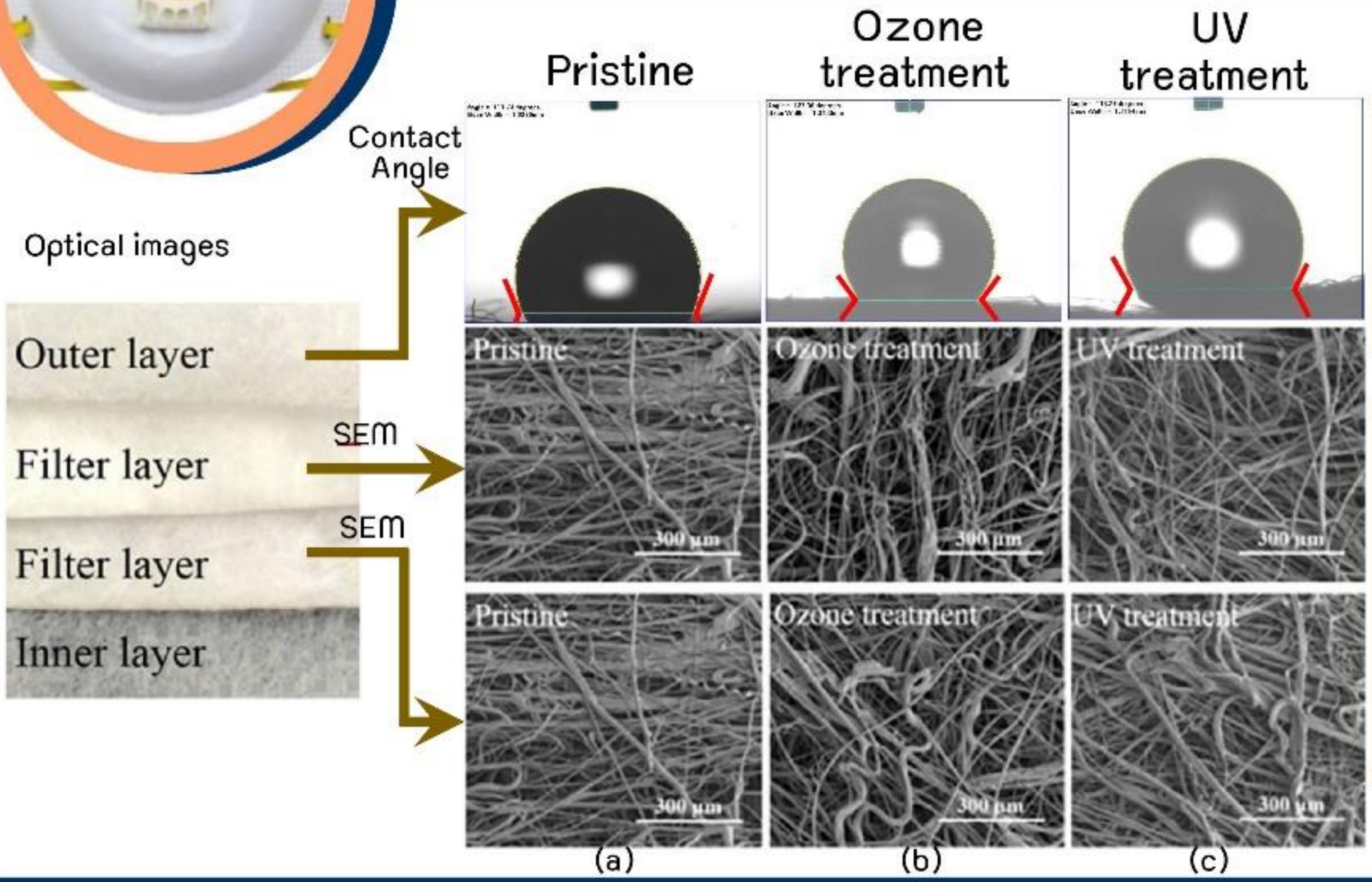
M 8 Results



Contact angle becomes slightly higher after UV and ozone treatments. However, the values are all higher than 90 degrees indicating that the masks are water resistance.

SEM images showing fiber structure of pristine (a) Ozone treated for 30 minutes (b) UV radiated at 120 mJ/cm^2 for 5 rounds (c) filter layers. Fiber structure (morphology and size) remain almost unchanged after treatments. Porosity of the filter fibers also does not change significantly.

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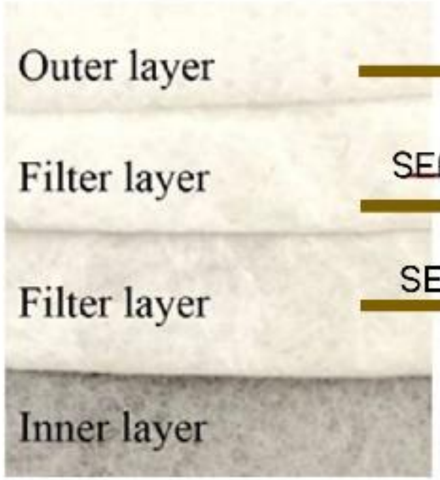
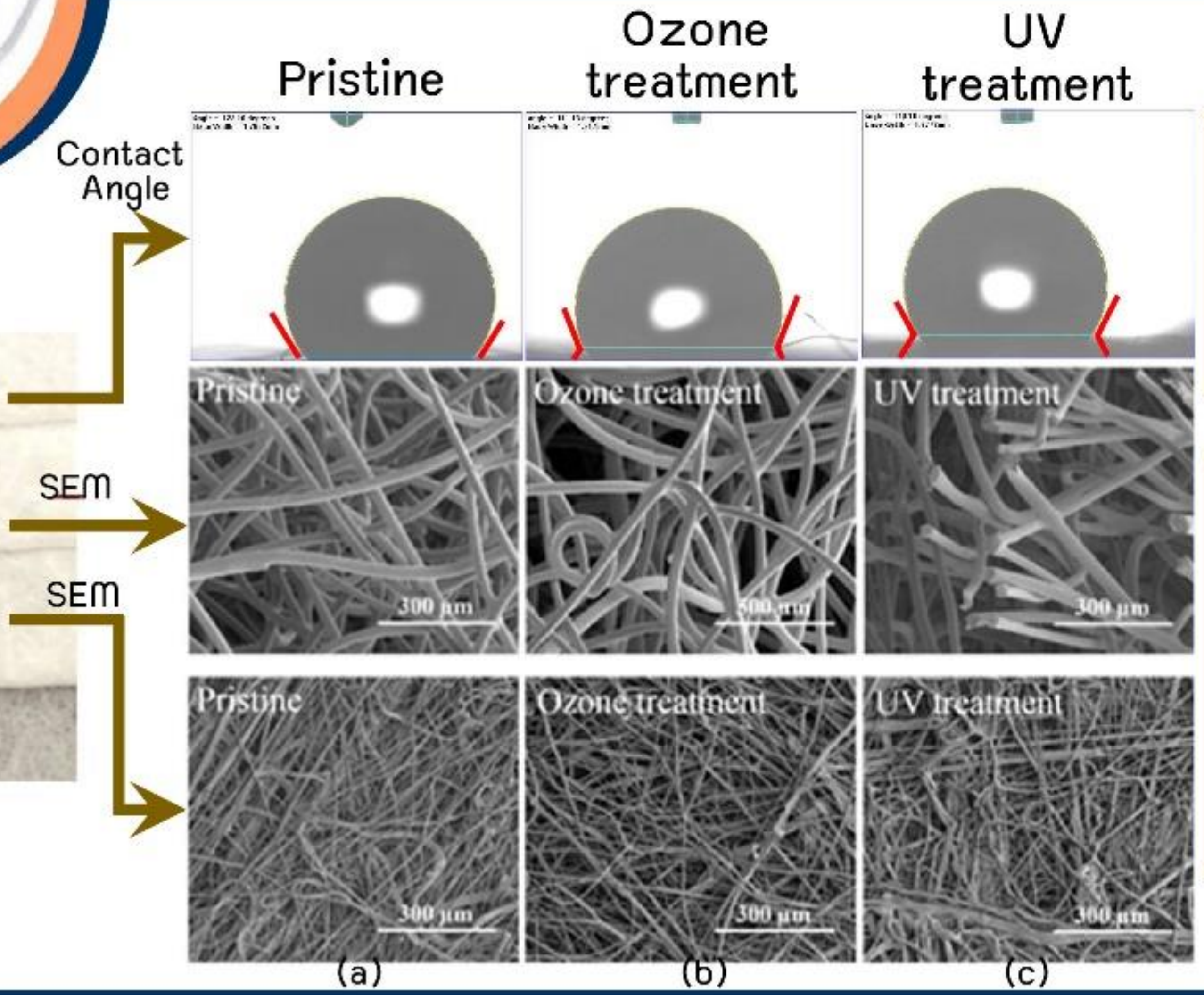
M 9 Results

Optical images





Contact angle becomes slightly lower after UV and ozone treatments. However, the values are all higher than 90 degrees indicating that the masks are water resistance.

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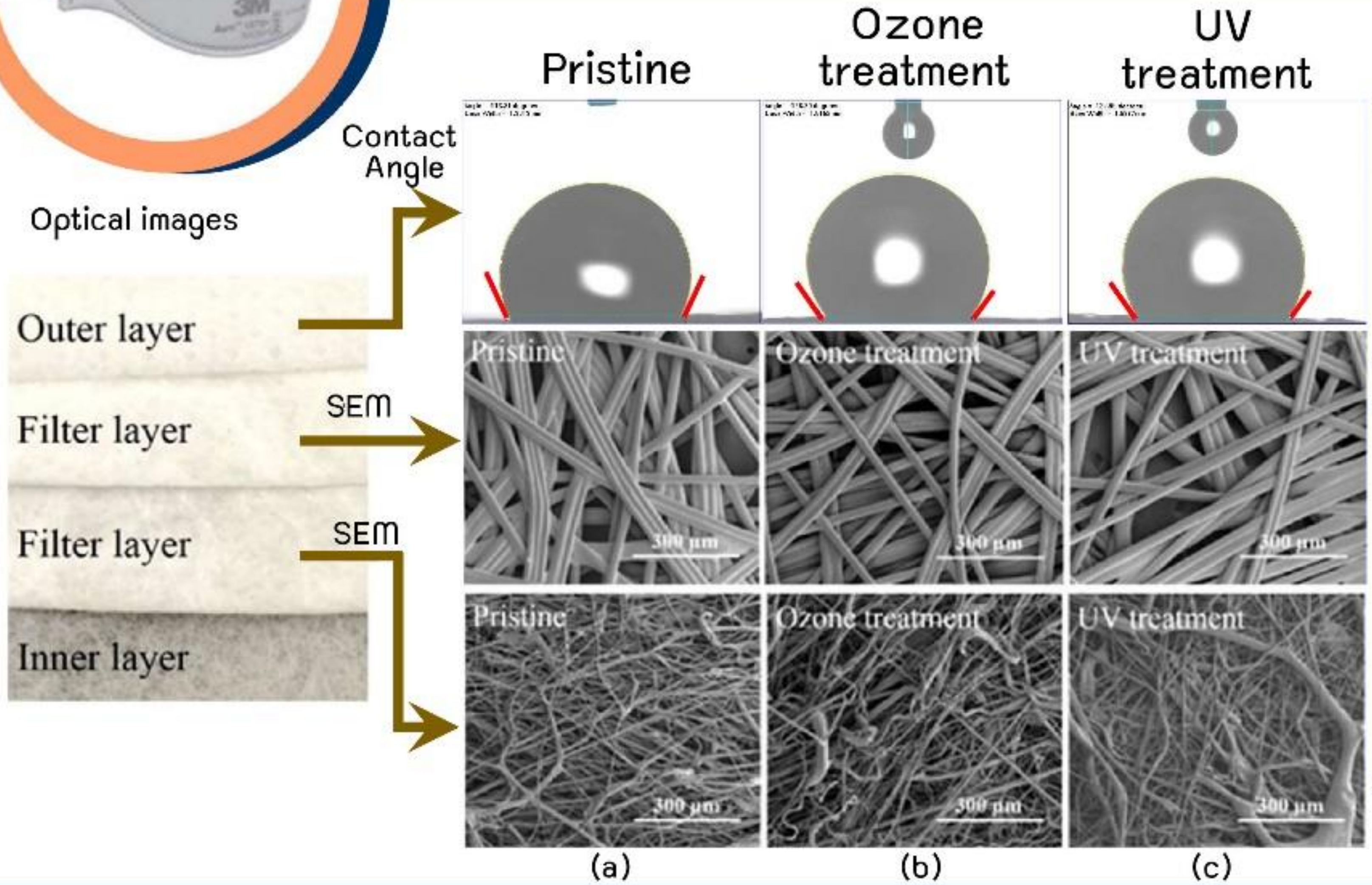
M 10 Results



Contact angle becomes slightly higher after UV and ozone treatments. However, the values are all higher than 90 degrees indicating that the masks are water resistance.

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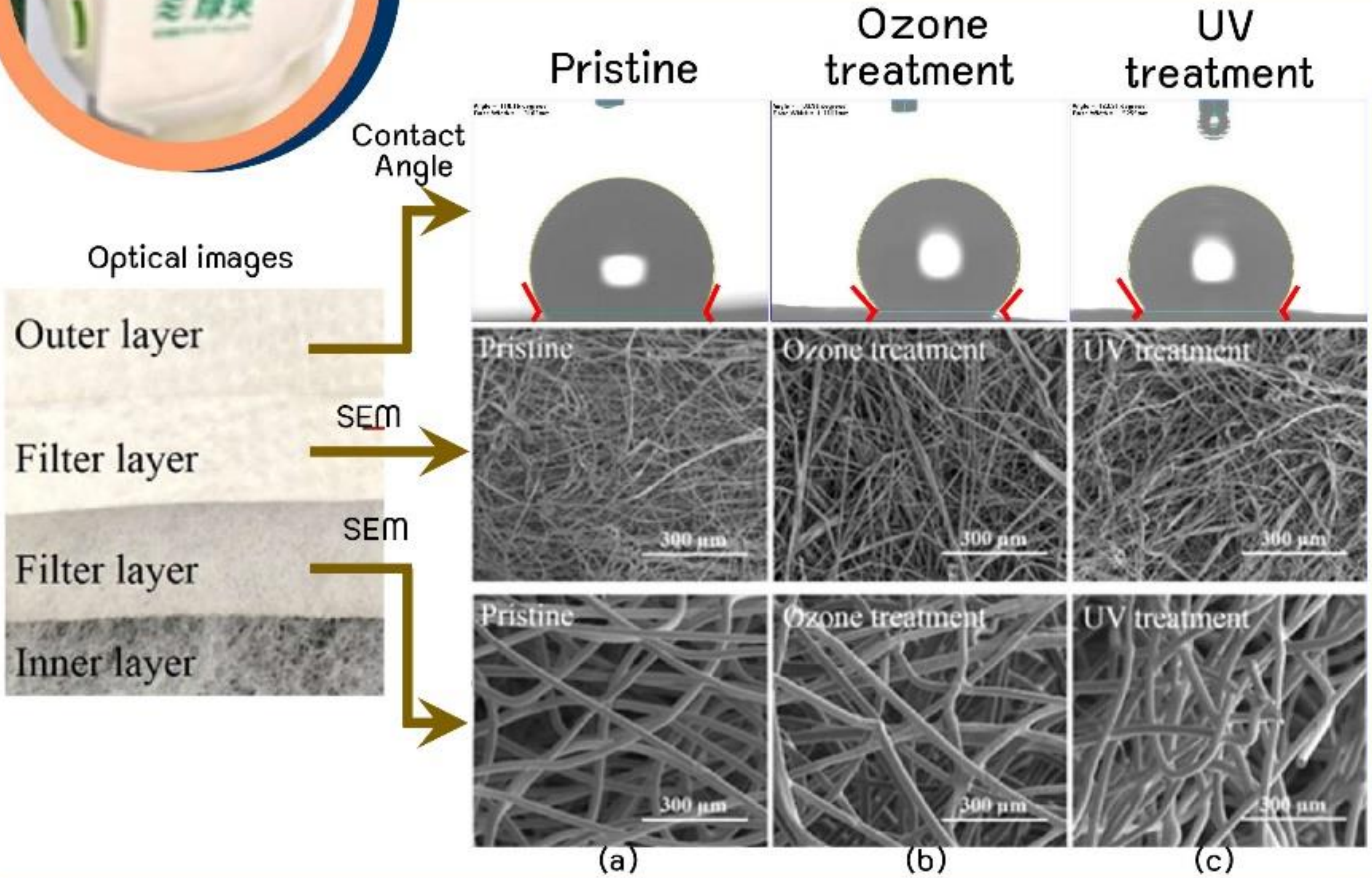
m 11 Results



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Sterility testing Results

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Cite: Faculty of Medicine and Faculty of Associated Medical Sciences, Khon Kaen University, April 3, 2020

UV treatment Microorganisms	Dosage (mJ/cm^2)						
	Control (Non treatment)	10	20	30	60	120	240
Gram-positive bacteria (*S. aureus*)	+	ND	ND	–	–	–	–
Gram-negative bacteria (*P. aeruginosa*)	+	ND	ND	+	+/–	–	–
Virus (ssRNA envelope virus)	+	+	+	–	–	–	–

Ozone treatment Microorganisms	Time (minutes)				
	Control (Non treatment)	15	30	60	120
Gram-positive bacteria (*S. aureus*)	+	–	–	–	–
Gram-negative bacteria (*P. aeruginosa*)	+	+	+/–	–	–
Virus (ssRNA envelope virus)	+	–	–	–	–

+ = Growth

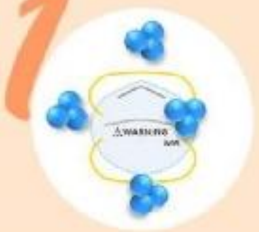
+/– = Partial growth

– = No growth

ND = Not detect

UV treatment can be used to eliminate *S. aureus*, *P. aeruginosa*, and ssRNA virus using UV dose of <20, >60, and >30 mJ/cm^2, respectively. **Ozone treatment** reveals the sterility capability to eliminate *S. aureus* and virus in 15 minutes, while *P. aeruginosa* were reduced in 30 minutes and eliminated in 60 minutes.

Conclusions



1 Ozone Treatment

can be used to effectively kill viruses. However, the ppm level of ozone needs to be ensured to exceed 5-10 ppm level. However, due to the toxicity of ozone gas, healthcare workers need to ensure that the masks are properly kept inside a sealed container while exposing them to ozone gas and wait for at least an hour before opening the container. .

This method is not recommended for the general public.

In this experiment, ozone concentration with high concentratoion **and the exposure time of 30 minutes** show no impact or physical damages to fiber structure (morphology and size) and porosity. Hydrophobicity (water resistance) of the outer layer of the N95 masks remains almost unchanged.

2 UV Radiation

can also be used to kill viruses with controlling UV radition dose (power of the UV source, distance away from the source, and exposure time). Controlling radiating temperature below 75 °C with long exposure time is the key to preserve the physical properties of the masks.

In this experiment, **UV dose of 120 mJ/cm^2** (which can be used to kill most common viruses and other microorganisms) is used. The N95 masks after **5 rounds of UV radiation** using these conditions show no physical damages to fiber structure (morphology and size) and porosity. Hydrophobicity of the outer layer of the N95 masks remains almost unchanged.

(Note: that if lower UV doses are used, more rounds of reuse can be anticipated. However, the ability to kill viruses using lower UV doses should be confirmed.)

Contributions

- **KKU Li-ion Battery Pilot Plant:** Experimental design, Sample preparation, Data analysis & Conclusions
- **Institute of Nanomaterials Research and Innovation for Energy (IN-RIE):** UV radiation and contact angle measurements
- **Faculty of Medicine and Faculty of Associated Medical Sciences:** Providing samples, Testing reduction/elimination of micro-organisms experiments.
- **Mr. Saksith Suwan** for Scanning Electron Microscopy (SEM) experiments
- **Dean and Assoc. Dean of Faculty of Science, VP of Innovation and Social Enterprise, and Mr. Chalermchai Vongnakpetch (KKU Council)** for supports

Cite: Institute of Nanomaterials Research and Innovation for Energy (IN-RIE), Faculty of Sciece, Khon Kaen University, April 2, 2020