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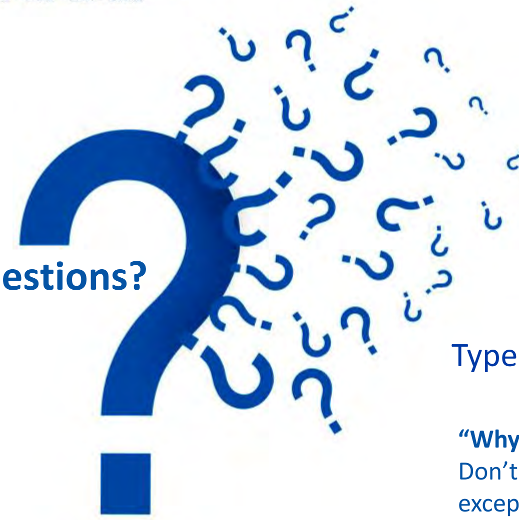

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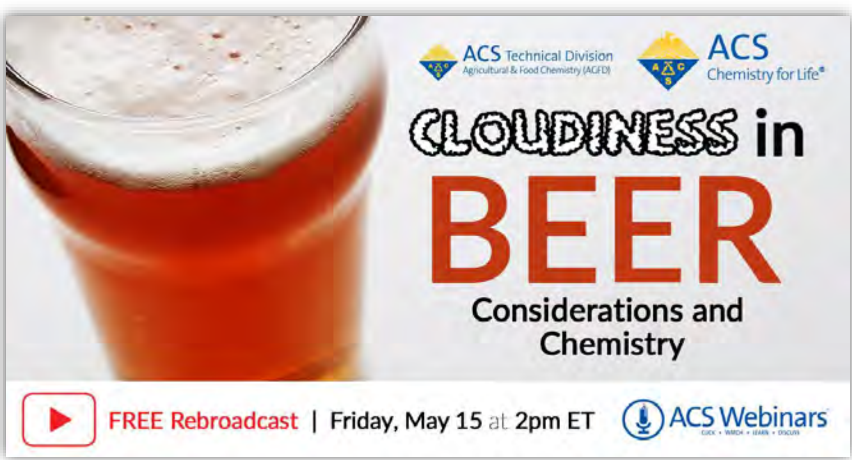


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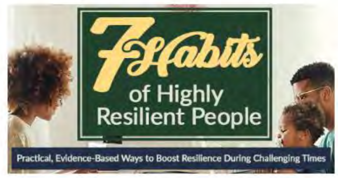
Monday, May 18, 2020 at 2-3pm ET
Speaker: Matt Grandbois, DuPont Electronics & Imaging
Moderator: Patricia Simpson, University of Illinois at Urbana-Champaign

Register for Free!

What You Will Learn

- How to perform a stakeholder analysis to understand how your efforts impact the people around you
- How to cultivate a healthy working relationship with your supervisor in order to meet your career goals
- Communication strategies for effective relationship building and goal setting

Co-produced with: ACS Division of Professional Relations




Tuesday, May 19, 2020 at 2-3pm ET
Speaker: Julie Neill, University of Maryland, Smith School of Business
Moderator: Tom Halleran, American Chemical Society

Register for Free!

What You Will Learn

- The mind/body connection (and how chemicals in the brain affect our health and mood)
- The fundamentals of Positive Psychology (and the factors that impact human well-being)
- How to reframe problems

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Wednesday, May 20, 2020 at 2-3pm ET
Speaker: Sandra Long, Post Road Consulting
Moderator: Tom Halleran, American Chemical Society

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What You Will Learn

- How to best position yourself on LinkedIn using effective language and visuals
- How to optimize your profile for search
- How to leverage the newest profile settings and features

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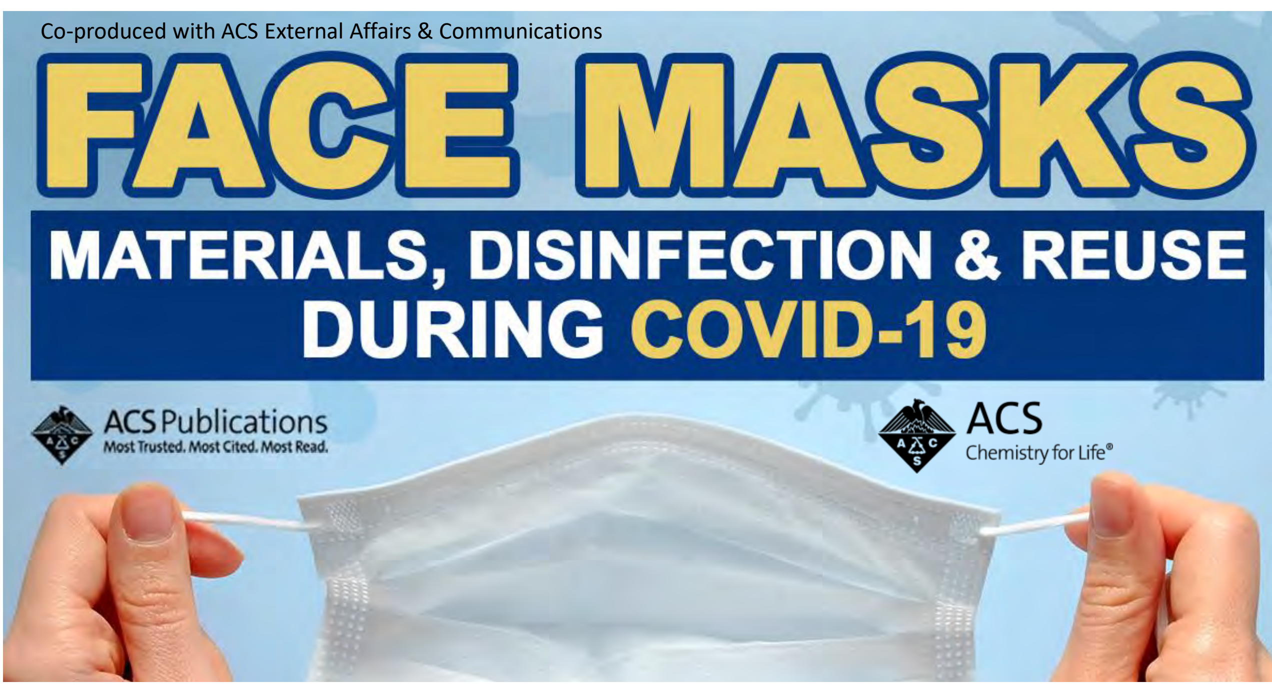


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## Face Masks: Materials, Disinfection, and Reuse During COVID-19

**Supratik Guha**
Professor, Pritzker School of Molecular Engineering, University of Chicago; and Scientist, Argonne National Laboratory

**Yi Cui**
Professor, Department of Materials Science and Engineering, Stanford University

**Laura Cassiday**
Senior Science Writer, External Affairs & Communications, American Chemical Society

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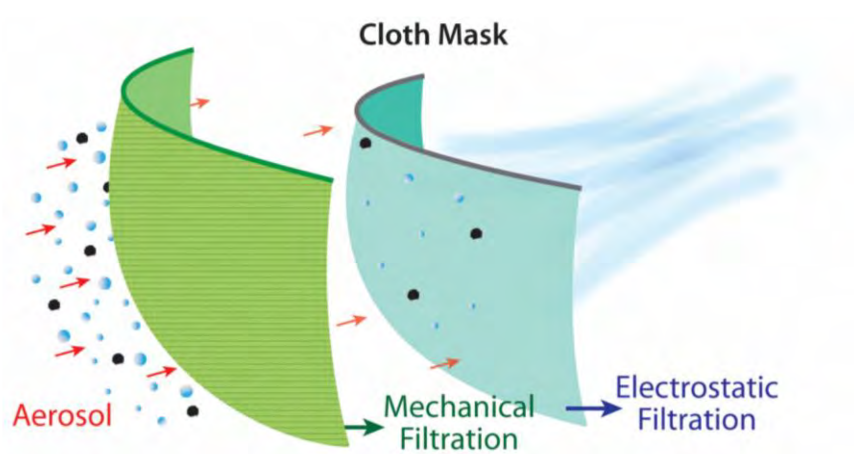
## Aerosol Filtration Efficiency of Common Fabrics Used in Respiratory Cloth Masks

*A. Konda, A. Prakash, G. A. Moss, M. Schmoldt, G.D. Grant, S. Guha*

https://pubs.acs.org/doi/abs/10.1021/acsnano.0c03252

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*Circa 1721*

| Mask Type | Standards | Filtration Effectiveness | | |
|---|---|---|---|---|
| Single-Use Face Mask  | China: YY/T0969 | 3.0 Microns: ≥95%<br>0.1 Microns: ✗ | | |
| Surgical Mask  | China: YY 0469 | 3.0 Microns: ≥95%<br>0.1 Microns: ≥30% | | |
| | USA: ASTM F2100 | Level 1 | Level 2 | Level 3 |
| | | 3.0 Microns: ≥95%<br>0.1 Microns: ≥95% | 3.0 Microns: ≥98%<br>0.1 Microns: ≥98% | 3.0 Microns: ≥98%<br>0.1 Microns: ≥98% |
| | Europe: EN 14683 | Type I | Type II | Type III |
| | | 3.0 Microns: ≥95%<br>0.1 Microns: ✗ | 3.0 Microns: ≥98%<br>0.1 Microns: ✗ | 3.0 Microns: ≥98%<br>0.1 Microns: ✗ |
| Respirator Mask  | USA: NIOSH (42 CFR 84)<br>China: GB2626 | N95 / KN95 | N99 / KN99 | N100 / KN100 |
| | | 0.3 Microns: ≥95% | 0.3 Microns ≥99% | 0.3 Microns ≥99.97% |
| | Europe: EN 149:2001 | FFP1 | FFP2 | FFP3 |
| | | 0.3 Microns: ≥80% | 0.3 Microns: ≥94% | 0.3 Microns: 99% |

**3.0 Microns:** Bacteria Filtration Efficiency standard (BFE).

https://smartairfilters.com/en/blog/comparison-mask-standards-rating-effectiveness

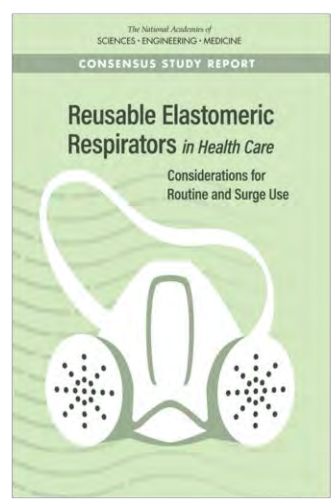
*~ 2020*



***National Academy Report on Respirators*** *(Mar 2019)*

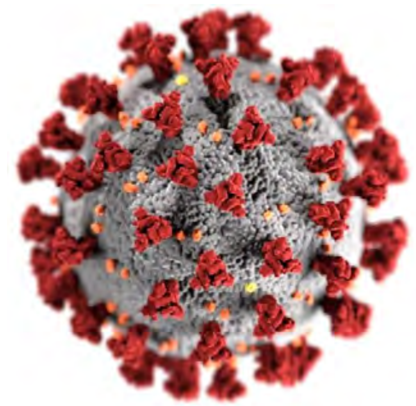
"……….Most U.S. health facilities use disposable filtering facepiece respirators, often called N95s. These respirators are to be discarded after one use. **Given recent concerns about pandemics and emergent diseases and the challenges experienced with supply chain limitations, reusable respirators are recommended.**

**Reusable respirators** (specifically, reusable half-facepiece elastomeric respirators) are the standard respiratory protection device used in many industries. **Their durability and reusability make them desirable for stockpiling for emergencies**, during which large volumes of respirators can be needed……………"



# Motivation

- **Cloth masks are being increasingly used**
- **Limited knowledge on the performance of different fabrics**
- **What is the effect of fit on the performance?**
  - **- Modeled by introducing gaps**



**60 nm – 140 nm**

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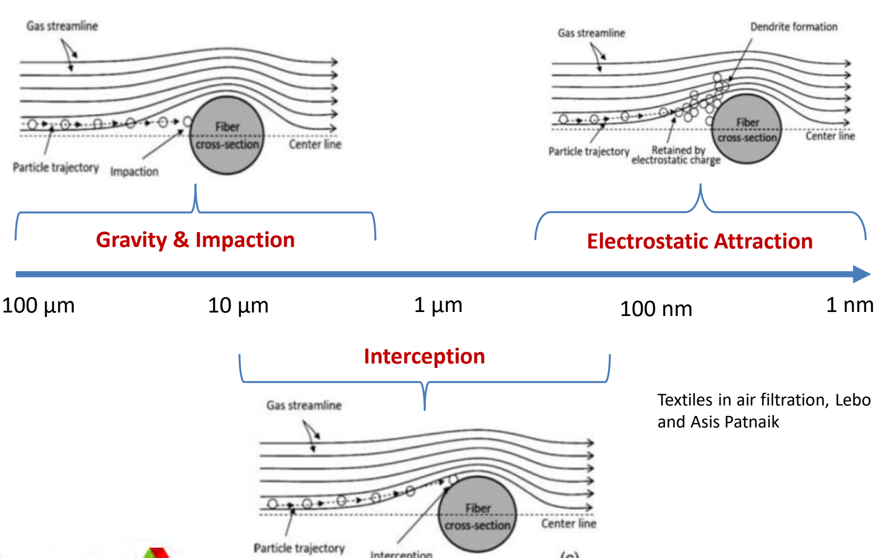
# Filtration Mechanisms




Textiles in air filtration, Lebo Maduna and Asis Patnaik

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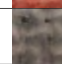
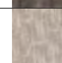
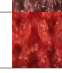
# Microstructure vs. Performance

| *Fabric Name* | *Composition* | *Microstructure (Optical image)* | *Porosity (%)* | *Thread Diameter (μm)* | *Thread Pitch (μm)* |
|---|---|---|---|---|---|
| Cotton Quilt | Two layers of 120 TPI cotton Filling: ~0.5cm (90% Cotton, 5% polyester, 5% other fibers) |  | 20.1 | 227 | 300-400 |
| Quilters Cotton #80 | 100% cotton |  | 14 | 270 | 460-500 |
| Cotton #600 | 100% cotton |  | <1 | 55-75 | 70-75 |
| Flannel | 100% cotton, 35% polyester |  | 15 | 300-440 | 500-650 |
| Chiffon | 90% polyester, 10% spandex |  | 3 | 200-250 | 220-320 |
| Natural Silk | 100% silk |  | 1.5 | 180-260 | 270-500 |
| Synthetic Silk | 100% polyester |  | 3 | 190-230 | 440-570 |
| Satin | 97% polyester, 3% spandex |  | 11 | 210 | 165-520 |
| Polyester | 100% woven polyester |  | 23 | 180-200 | 300-500 |

Konda et al. *ACS Nano* **2020.**

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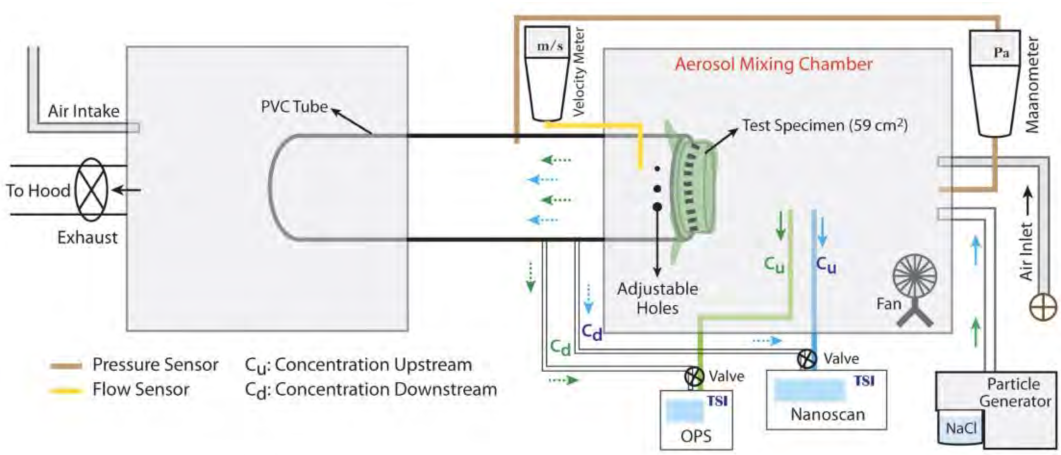
# Experimental Set-up




Optical particle sizer (300 – 6000 nm)

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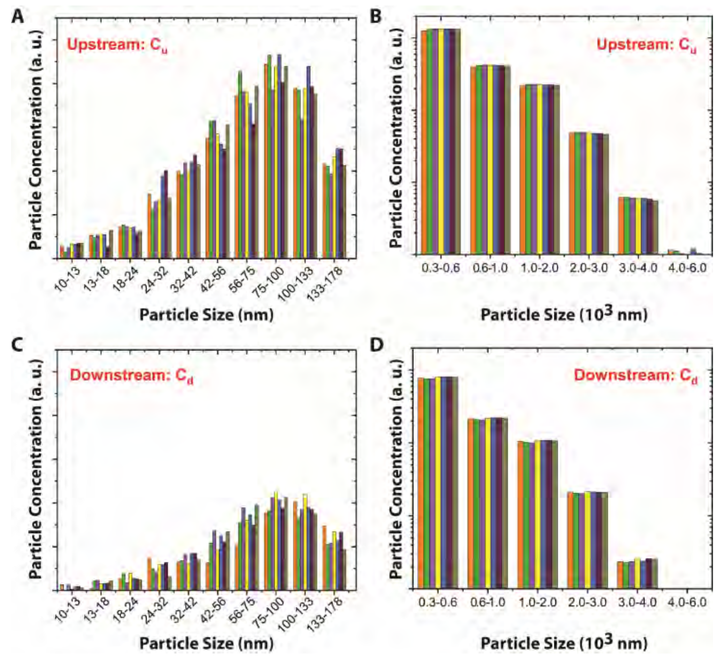
# Determining Filtration Efficiency

## Filtration Efficiencies

$$FE = \frac{C_u - C_d}{C_u}$$

At least six measurements used to calculate weighted average

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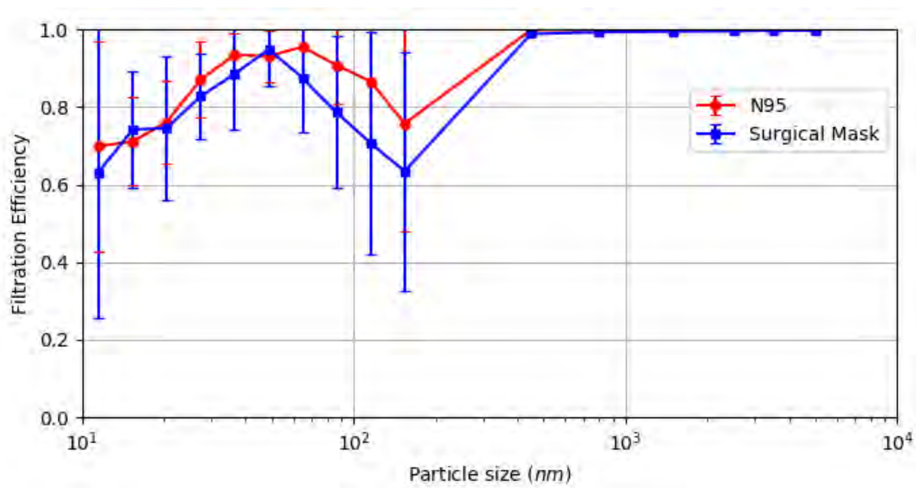
# Analyzing Concentration Data

## Filtration Efficiencies

$$FE = \frac{C_u - C_d}{C_u}$$

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# Different Fabrics

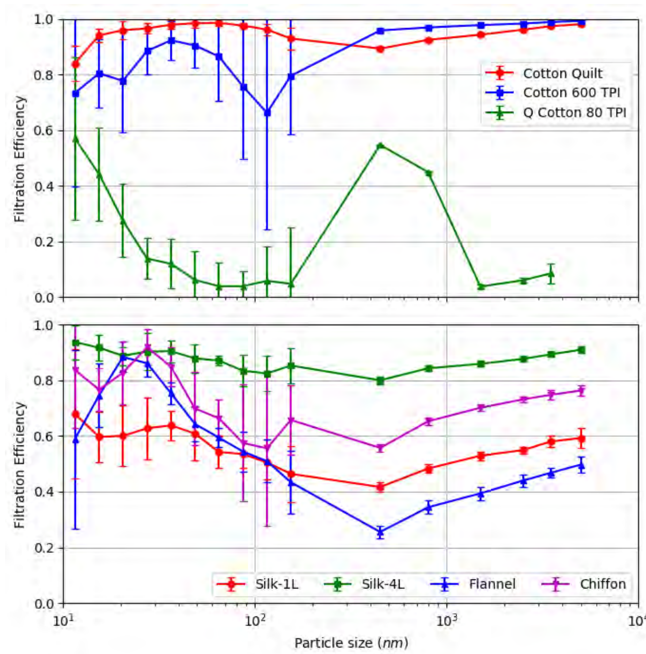
- **The performance is based on**

- **Weave/tightness of threads**

**Mechanical Filtration**

- **The material properties**

**Electrostatic Filtration**

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- With plans for reopening, strong demand for cloth masks from procurement offices
- Supply chain for cloth masks stressed

**DRAFT OF A "SPEC DOCUMENT" (MIKE SCHMOLDT, ARGONNE)**

Samples will be evaluated on the level of protection provided (50%), ability to be worn effectively (40%) and durability (10%).

**Materials of Construction:**

- At least 2 layers of fabric or non-woven materials
  - For woven materials, a thread count of at least at >80 threads per inch, with higher thread counts up to 600 TPI preferred
  - A cotton or cotton blend outer layer
- A cotton, cotton blend or synthetic fabric inner layer

**Exclusions:**

- Open mesh fabrics such as jersey or spandex weaves or are not acceptable
- Exhalation valves are not acceptable

**General Requirements:**

- Fit snugly but comfortably against the side of the face and chin without gaps
- Be able to closely fit around the nose, preferably with an adjustable or moldable structure to fit snugly and retain it's shape during use
- Be secured with ties or elastic ear loops
- Allow for breathing without restriction
- Be able to be consumer laundered and machine dried multiple times without damage or change to shape
- Be a universal size for adult workers or provide more than one size for varying facial shapes and sizes

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Aerosol Filtration Efficiency of Common Fabrics used in Respiratory Cloth Masks.
American Chemical Society, Nano. April 24, 2020.
https://pubs.acs.org/doi/10.1021/acsnano.0c03252

# Outlook

- Tight weaves better than open weaves
- Look for surface area
- Hybrids for combining electrostatic + mechanical filtration
- Effect of Humidity and washability
- Future opportunity → washable, reusable masks replace one-time use masks in many less critical circumstances.

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Stanford ENGINEERING Materials Science & Engineering | 4C Air

# Facial Masks during COVID-19: Disinfection, Homemaking and Imaging

Prof. Yi Cui
Department of Materials Science and Engineering, Stanford University
SLAC National Accelerator Laboratory

Collaborators:
Stanford: Prof. Steven Chu, Prof Larry Chu, Prof. Wah Chiu, Dr. Amy Price, Dr. Hye Ryoung Lee
SLAC (X-ray imaging): Johanna Nelson Wekker, Yijin Liu, Prof Piero Pianetta
4C Air Team: Dr. Lei Liao, Mervin Zhao and others
The DeMaND Team: Prof. May Chu (Colorado), Selcen Kilinc-Balci (CDC/NIOSH), Brian H. Harcourt (CDC) Ying Ling Lin (WHO) and many others

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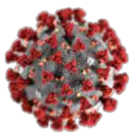
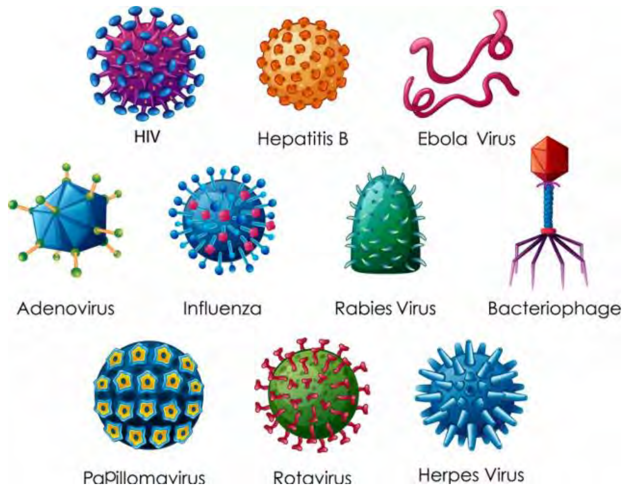
# Virus sizes : 20 nm to 400 nm

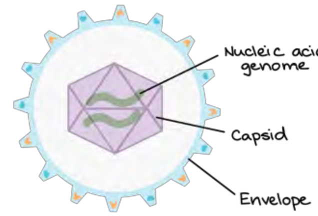
SARS-COV-2
(～150nm)

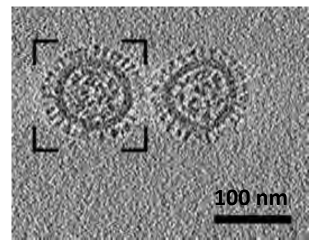


- related to SARS and MERS
- spread *via* close contact
- infect lung cells
- cause pneumonia




Virus Structures




Influenza virus

Image adapted from Google

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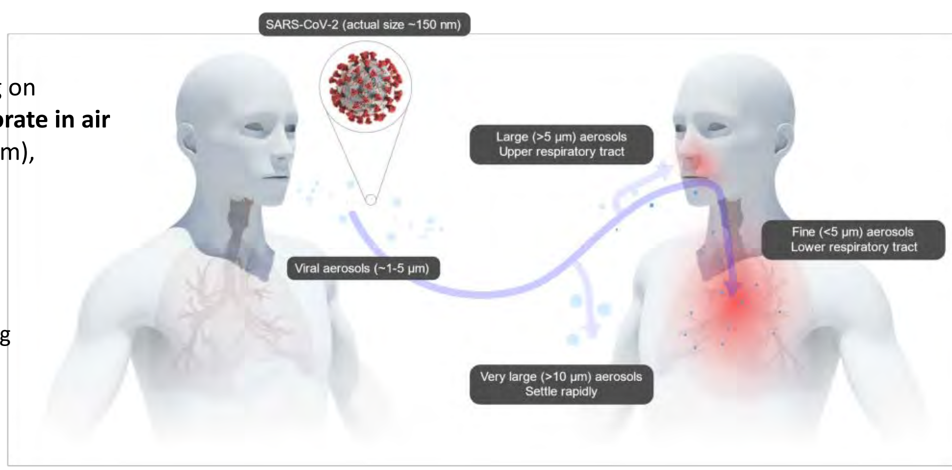
**After seconds** (depending on humidity)**, droplets evaporate in air to become aerosols** (<1 μm)**, which stay in air for days.**

**Indoor:** wearing masks

**Outdoor:** If crowded, wearing masks




https://www.medrxiv.org/content/10.1101/2020.04.01.20050443v1

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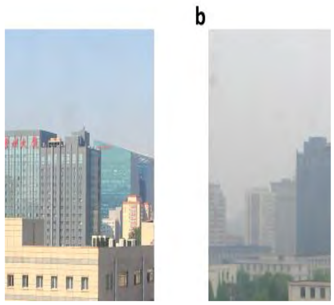
# Filtration materials in mask



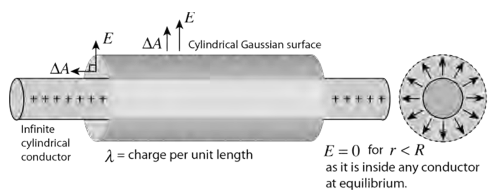

**Spunbond fibers:** 10–40 μm diameter

**Meltblown fibers:** 1–10 μm diameter

1) Micronsize fibers (1–10 μm ) forming 3D structures with porosity ~90%

2) Need electric static charge to increase particle capture efficiency

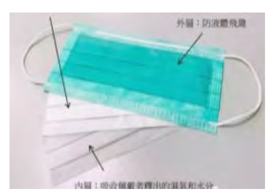
For $r \geq R$ $$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

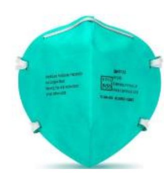



http://hyperphysics.phy-astr.gsu.edu/hbase/electric/elecyl.html



# Mask Standards





| Mask Type | Single-use medical face mask | Surgical Mask | Protective face mask for medical use |
|---|---|---|---|
| Standards | YY/T 0969-2013 | YY 0469-2011 | GB19083-2010 |
| Particle size | 3μm bacteria aerosol | 3μm bacteria aerosol<br>0.3μm NaCl aerosol | 0.3μm NaCl aerosol |
| Filtration efficiency<br>particle filtration efficiency (PFE)<br>Bacteria filtation efficiency (BFE) | BFE≥95% | BFE≥95%<br>PFE≥30% | PFE≥95% (I)<br>PFE≥99% (II)<br>PFE≥99.97% (III) |
| | | | |
| Liquid blocking capability, mmHg | / | ≥120 | ≥80 |

# Mask Standards

| Mask types | Protective face mask for medical use | Industrial Protective Mask | Daily Protective masks |
|---|---|---|---|
| Standards | GB 19083-2010 | GB 2626-2019 | GB/T 32610-2016 |
| Particle size | 0.3μm NaCl aerosol (mass median size) | 0.3μm NaCl aerosol | 0.3μm NaCl aerosol |
| Filtration efficiency<br>Particle filtration efficiency (PFE)<br>Bacteria filtation efficiency (BFE)) | PFE≥95% (I)<br>PFE≥99% (II)<br>PFE≥99.97% (III) | PFE≥90%<br>PFE≥95%<br>PFE≥99.97% | PFE≥90% (III)<br>PFE≥95% (II)<br>PFE≥99% (I) |
| Liquid blocking capability, mmHg | 80 | / | / |

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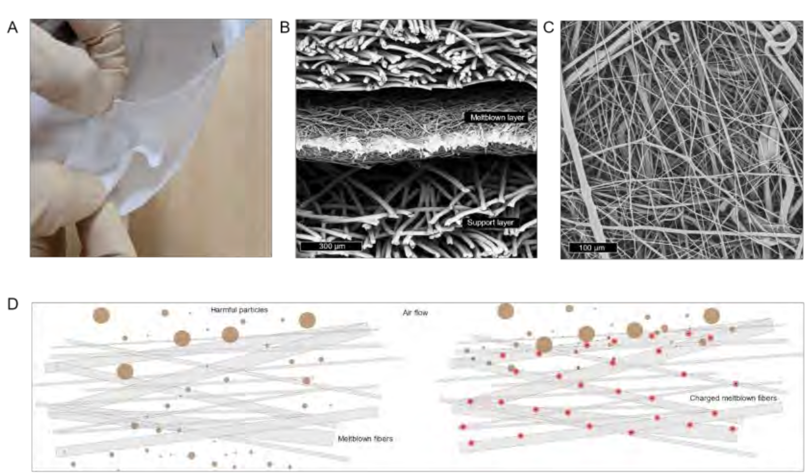
# Filtration materials in mask

ACS NANO
www.acsnano.org

**Can N95 Respirators Be Reused after Disinfection? How Many Times?**

Lei Liao, Wang Xiao, Mervin Zhao, Xuanze Yu, Haotian Wang, Qiqi Wang, Steven Chu, and Yi Cui*

Cite This: https://dx.doi.org/10.1021/acsnano.0c03597 Read Online

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**Similar as the NIOSH-testing condition**
TSI 8130A, 0.26um NaCl particles (mean mass diameter),
**Fabric level:** 32 L/min flow
**Mask level:** 85 L/min flow

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# N95 Meltblown Fabric Disinfection

Stanford ENGINEERING Materials Science & Engineering

4C Air

TSI 8130A, 0.26um NaCl particles, 32 L/min flow

| Samples | Meltblown fiber filtration media | | Static-charged cotton | | E. Coli. Disinfection Efficiency |
|---|---|---|---|---|---|
| | Filtration efficiency (%) | Pressure drop (Pa) | Filtration efficiency (%) | Pressure drop (Pa) | |
| 70℃ hot air in oven, 30min | 96.60 | 8.00 | 70.16 | 4.67 | >99% |
| UV light, 30min | 95.50 | 7.00 | 77.72 | 6.00 | >99% |
| 75% alcohol, soaking and drying | 56.33 | 7.67 | 29.24 | 5.33 | >99% |
| Chlorine-based disinfection, 5min | 73.11 | 9.00 | 57.33 | 7.00 | >99% |
| Hot water vapor from boiling water, 10min | 94.74 | 8.00 | 77.65 | 7.00 | >99% |
| Initial samples before treatment | 96.76 | 8.33 | 78.01 | 5.33 | |

Conclusion:
Do not use alcohol-based or Chlorine-related chemicals for mask disinfection since they will reduce the static charge in meltblown micron fibers and cottons, and thus reduce the filtration efficiency.

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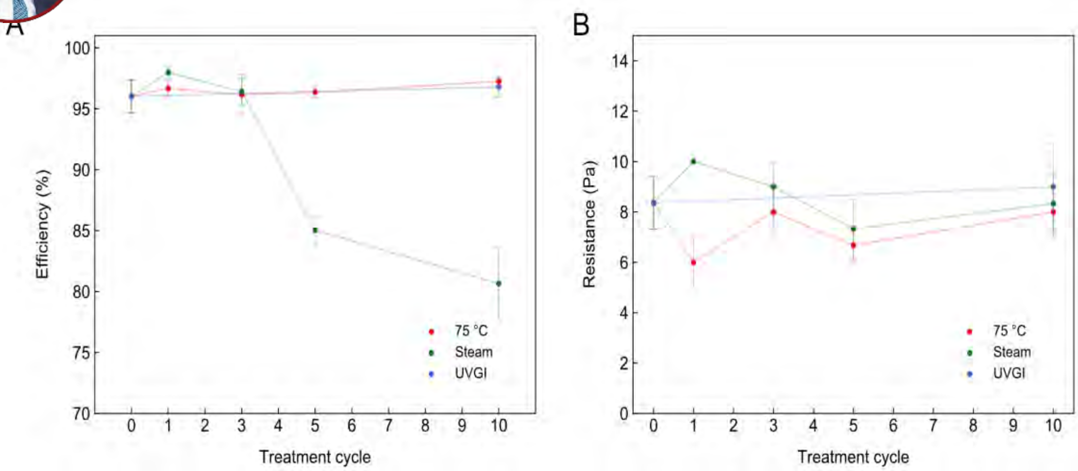


https://dx.doi.org/10.1021/acsnano.0c03597

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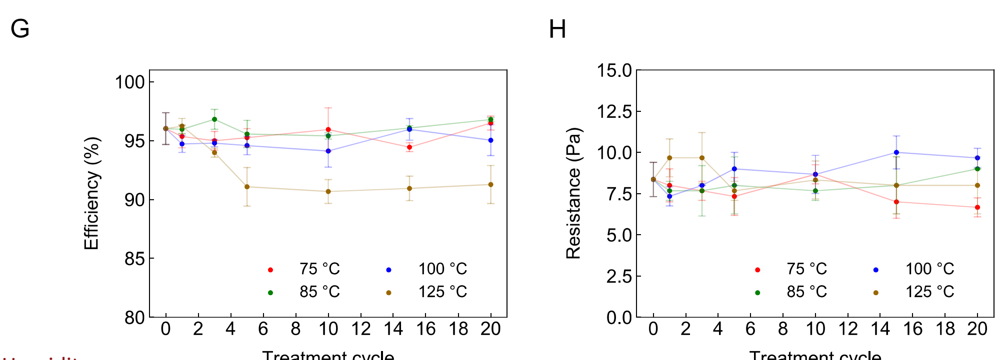
4C Air

## N95 Meltblown Fabric Disinfecting Cycling




**Dry heat:** <30% Humidity

75°C, 30min
85°C, 20min
100°C, 10min
125°C, 10min

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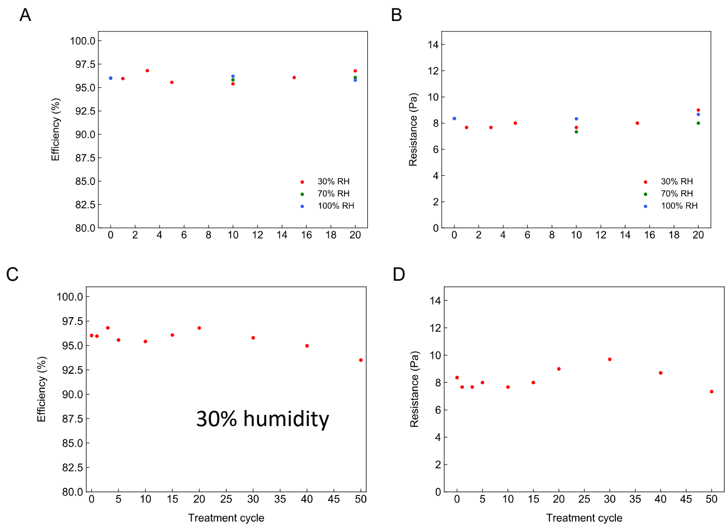


**Each Cycle:** 20 min 85°C/per cycle, different humidities

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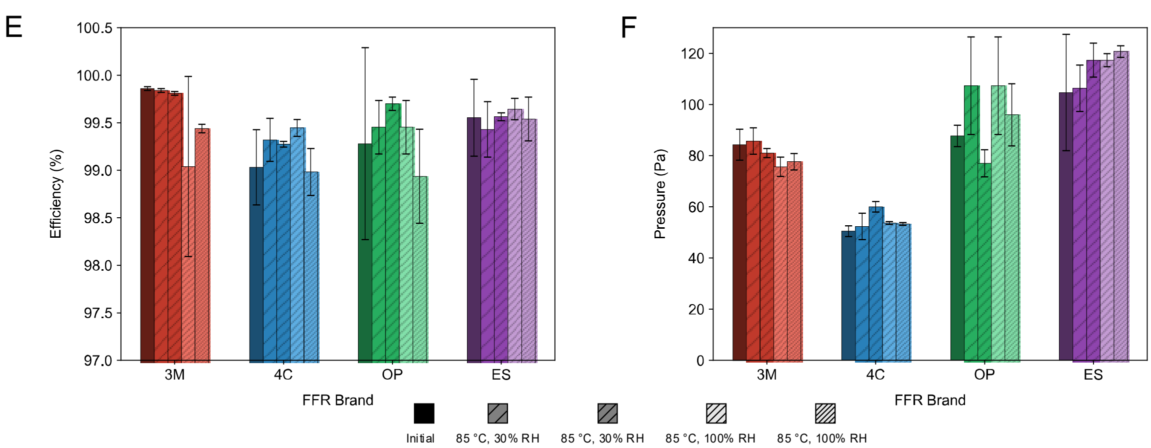
## N95 Mask Disinfecting Cycling




20 min 85°C/per cycle

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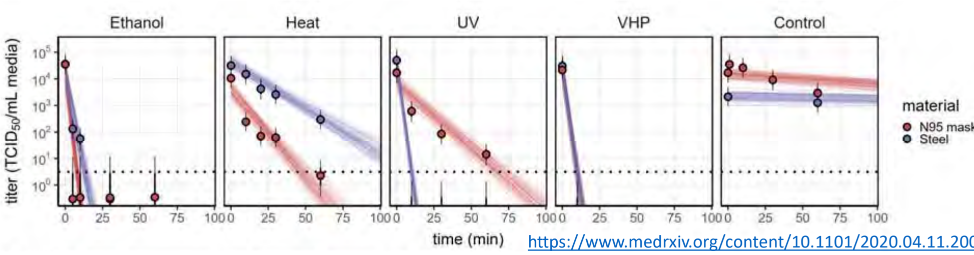
## Heat (dry, humid) on COVID-19 Disinfection

Table. Stability of SARS-CoV-2 at different environmental conditions.

| Time | Virus titre (Log $TCID_{50}$/mL) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 4°C | | 22°C | | 37°C | | 56°C | | 70°C | |
| | Mean | ±SD | Mean | ±SD | Mean | ±SD | Mean | ±SD | Mean | ±SD |
| 1 min | N.D. | N.D. | 6.51 | 0.27 | N.D. | N.D. | 6.65 | 0.1 | 5.34 | 0.17 |
| 5 mins | N.D. | N.D. | 6.7 | 0.15 | N.D. | N.D. | 4.62 | 0.44 | U | - |
| 10 mins | N.D. | N.D. | 6.63 | 0.07 | N.D. | N.D. | 3.84 | 0.32 | U | - |
| 30 mins | 6.51 | 0.27 | 6.52 | 0.28 | 6.57 | 0.17 | U | - | U | - |
| 1 hr | 6.57 | 0.32 | 6.33 | 0.21 | 6.76 | 0.05 | U | - | U | - |
| 3 hrs | 6.66 | 0.16 | 6.68 | 0.46 | 6.36 | 0.19 | U | - | U | - |
| 6 hrs | 6.67 | 0.04 | 6.54 | 0.32 | 5.99 | 0.26 | U | - | U | - |
| 12 hrs | 6.58 | 0.21 | 6.23 | 0.05 | 5.28 | 0.23 | U | - | U | - |
| 1 day | 6.72 | 0.13 | 6.26 | 0.05 | 3.23 | 0.05 | U | - | U | - |
| 2 days | 6.42 | 0.37 | 5.83 | 0.28 | U | - | U | - | U | - |
| 4 days | 6.32 | 0.27 | 4.99 | 0.18 | U | - | U | - | U | - |
| 7 days | 6.65 | 0.05 | 3.48 | 0.24 | U | - | U | - | U | - |
| 14 days | 6.04 | 0.18 | U | - | U | - | U | - | U | - |

A) Temperature* https://www.medrxiv.org/content/10.1101/2020.03.15.20036673v2.full.pdf+html

70°C in solution, 5min, Complete Disinfection




https://www.medrxiv.org/content/10.1101/2020.04.11.20062018v1

70°C Dry Heat, 60min, Complete Disinfection

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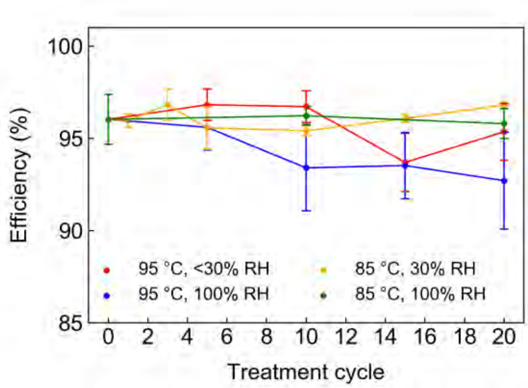
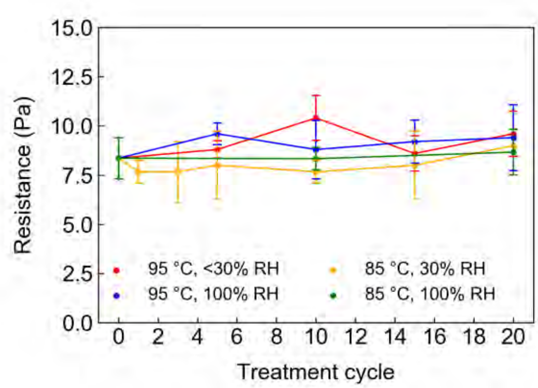
## Heat Under Different Humidity on N95 Meltblown Fabric

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# Summary of Heating Methods

Dry heat below 100C is safe for N95 Meltblown Fabric

Humid heat below 95C (<100C ) is safe for N95 Meltblown Fabric

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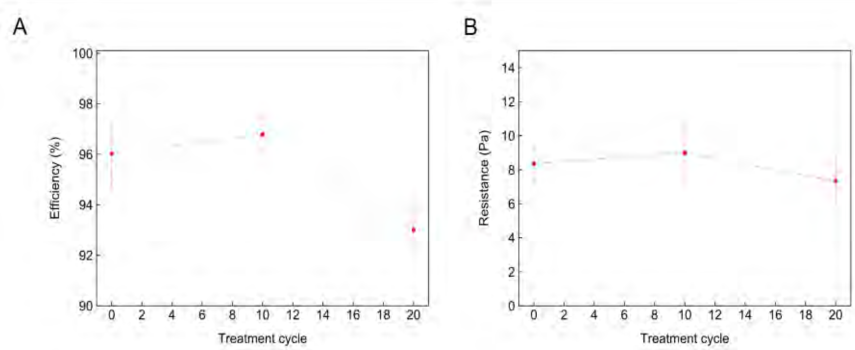
# UV Testing, 254nm, 8W light bulb




**Notes on the UV-C methods:**

1) Penetration; The shadow effects of 3D porous structures
2) UV illumination uniformity issue
3) UV Dose measurement
4) UV degradation of PP fibers and elastic straps.

Implementing the UV-C method requires good engineering control, probably more suitable for industry scale disinfection.

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## Notes on other disinfection methods

1) **Ethylene oxide:** toxic, needs to release the residue (need to good engineering control, Industry scale)

2) **Vaporized hydrogen peroxide:** cautious about the toxic byproduct, needs to release the residue (need to good engineering control, Industry scale)

3) **$ClO_2$:** cautious about toxic by product, etching straps, needs to release the residue (need to good engineering control, Industry scale)

4) **Ozone:** cautious about toxic by product, needs to release the residue (need to good engineering control, Industry scale)

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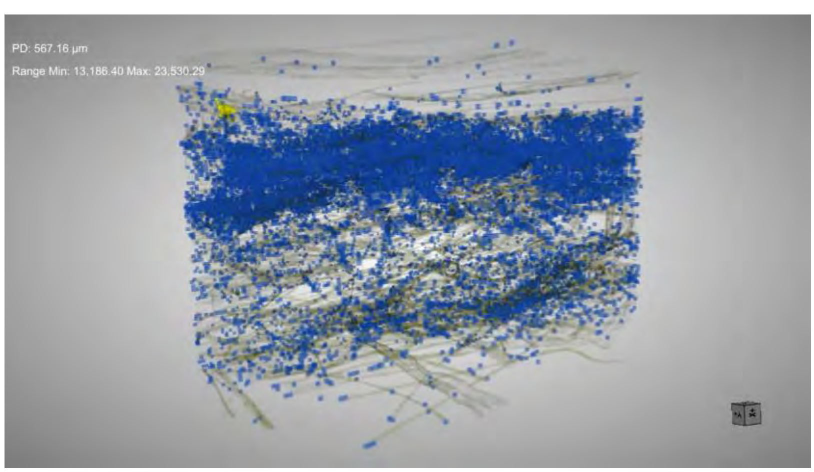
## NaCl particle distribution inside N95 Meltblown fabric




X-Ray CT

Hye Ryoung Lee, Yi Cui et. al. unpublished results

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## Household Materials for Homemade masks


Kitchen paper towel | Facial tissue | Xerox A4 paper

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Yi Cui et. al. unpublished results

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## Material selection

$$Q = -\frac{\log\left(1 - \frac{E}{100}\right)}{\Delta P}$$

| Material | Source | Structure | Basis weight (g/m²) | Initial Efficiency (%) | Initial Pressure drop (Pa) | Filter quality factor, Q (kPa⁻¹) |
|---|---|---|---|---|---|---|
| **Personal Protection Materials** | | | | | | |
| **Polypropylene 1** | Particulate FFR | Meltblown (nonwoven) | 25 | 95.94 ± 2 | 9.0 ± 2.0 | 162.7 ± 21.3 |
| **Polypropylene 2** | Surgical mask | Meltblown (nonwoven) | 26 | 33.06 ± 0.95 | 34.3 ± 0.5 | 5 ± 0.1 |
| **Polypropylene 3** | Surgical mask | Meltblown (nonwoven) | 20 | 18.81 ± 0.5 | 16.3 ± 0.5 | 5.5 ± 0.1 |
| **Household Materials** | | | | | | |
| **Polypropylene 4 (PP-4)** | Spunbond | Nonwoven | 30 | 6.15 ± 2.18 | 1.6 ± 0.5 | 16.9 ± 3.4 |
| **Cotton 1†** | Clothing | Woven | 116 | 5.04 ± 0.64 | 4.5 ± 2.1 | 5.4 ± 1.9 |
| **Cotton 2†** | Clothing | Knit | 157 | 21.62 ± 1.84 | 14.5 ± 2.1 | 7.4 ± 1.7 |
| **Cotton 3†** | Clothing | Knit | 360 | 25.88 ± 1.41 | 17 ± 0.0 | 7.6 ± 0.4 |
| **Polyester** | Clothing | Knit | 200 | 17.5 ± 5.1 | 12.3 ± 0.5 | 6.8 ± 2.4 |
| **Silk** | Napkin | Knit | 84 | 4.77 ± 1.47 | 7.3 ± 1.5 | 2.8 ± 0.4 |
| **Nylon** | Clothing | Woven | 164 | 23.33 ± 1.18 | 244 ± 5.5 | 0.4 ± 0 |
| **Cellulose** | Kitchen towel | Bonded | 42.9 | 10.41 ± 0.28 | 11 ± 0.0 | 4.3 ± 2.8 |
| **Cellulose** | Facial tissue | Bonded | 32.8 | 20.2 ± 0.32 | 19 ± 1 | 5.1 ± 3.2 |
| **Cellulose** | Copy paper | Bonded | 72.8 | 99.85 ± 0.02 | 1883.6 ± 39.3 | 1.5 ± 0.2 |

Yi Cui et. al. unpublished results

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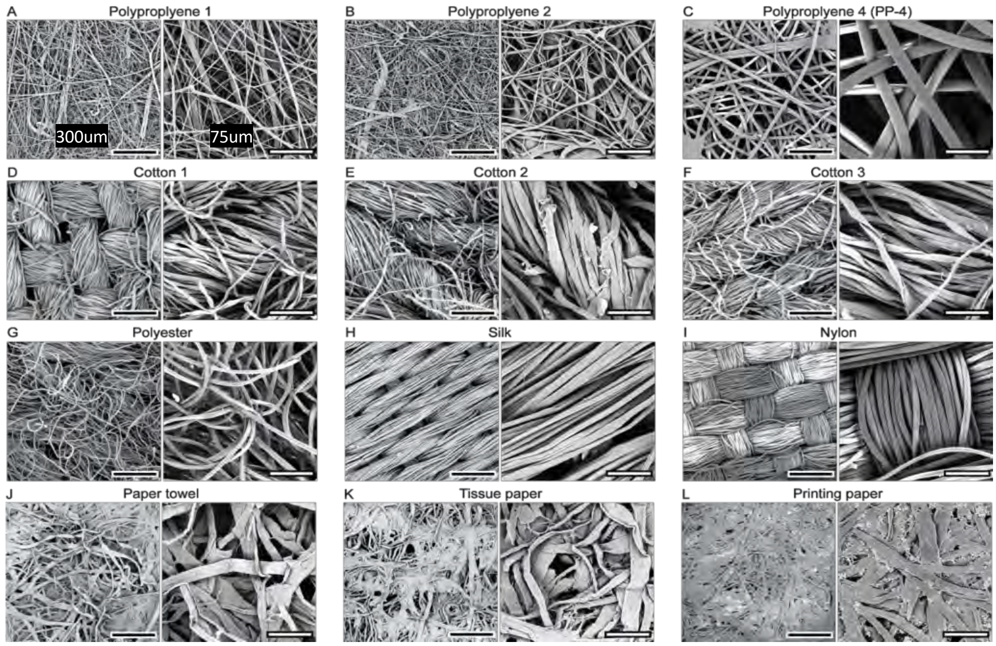


Yi Cui et. al. unpublished results

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## Acknowledgement

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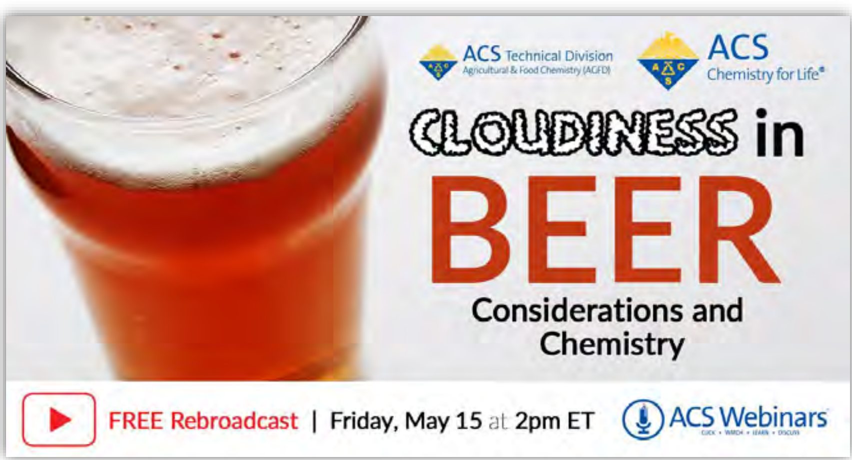


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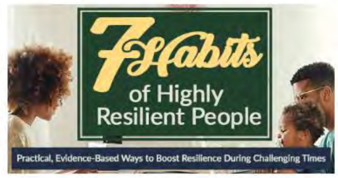


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