Study of Relative Humidity on Efficiency and Pressure Drop of Electret Media in the Loading Process

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Outline

- Introduction
- Experimental
- Results and discussion
- Conclusion

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Introduction

- A time budget study in US estimated that people spend an average of 87.2% of their time indoors (Robinson & Nelson, 1995). Therefore, the control of indoor air quality is an increasingly recognized problem.
- To reduce human exposure to particulate matter, filtration techniques such as HVAC filtration system and indoor air cleaners are used.
- Electret filters were widely used due to their ability to capture fine particles efficiently by electrostatic force while offering a minimum of flow resistance.

Introduction

- The electret air filters are used in different environments with varying temperature and relative humidity (RH).

Literature review:

Effect of RH on initial efficiency of electret media

- Yang et al. (2007) reported a significant drop of initial efficiency under RH 70%.
- Moyer & Stevens (1989), Otani et al. (1993), Walsh & Stenhouse (1998) and Myers & Arnold (2003) reported that there is no effect of humidity on the initial efficiency.
- Ackley (1982) found that a combination of high temperature and high humidity was required for efficiency to decrease.

Effect of RH on loading performance of electret media

- Montgomery et al. (2015) studied the effect of RH on pressure drop and efficiency in the loading of electret media, but no results on efficiency evolution in the loading.

Introduction

Goal:

- Study the efficiency and pressure drop evolution in the loading process under different relative humidity.
- Understand the fundamental of the impact of relative humidity on electret filtration.

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2. Experimental

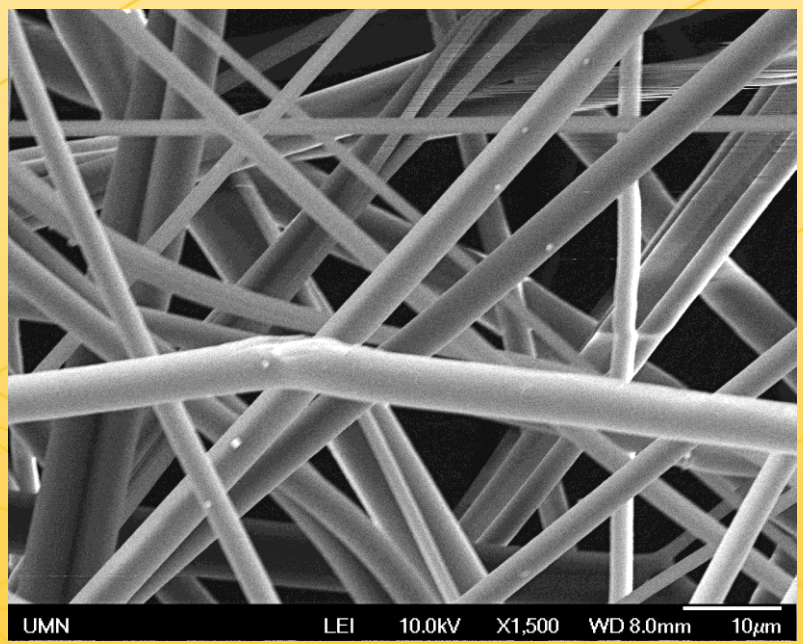
❑ Electret Filter Media

Properties of electret media

Thickness, mm	0.508
Effective Fiber Diameter, μm	9
Charge Level	High
Basis weight, g/m^2	32
Solidity (volume density)	7%

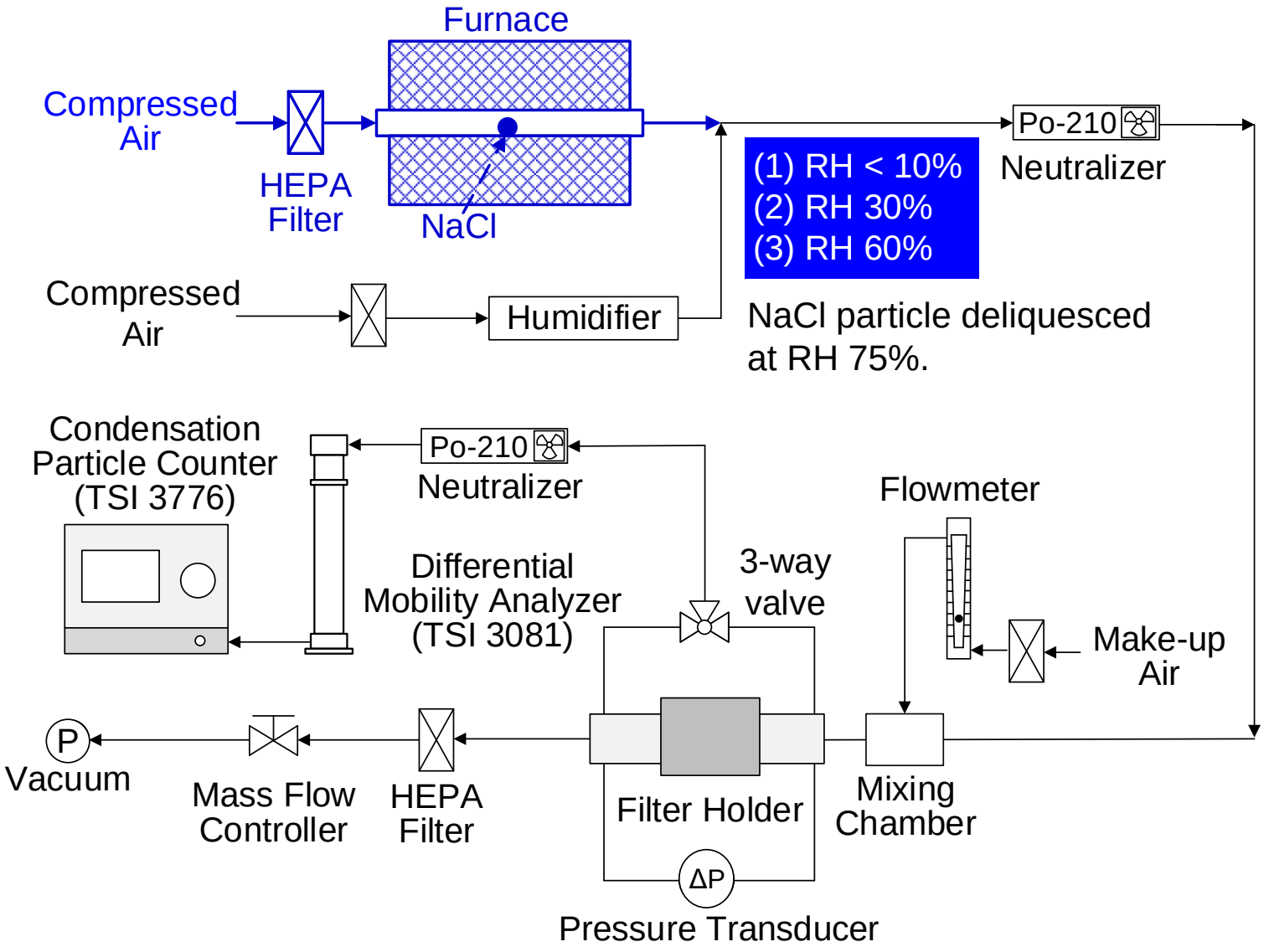
Data from manufacturer

- The equilibrium moisture content of polypropylene fiber at 21^{o}C and 65% RH is 0. (Hutten, 2016)



SEM image of electret media (Depth filtration media)

Loading particles were generated by vaporization-condensation method.

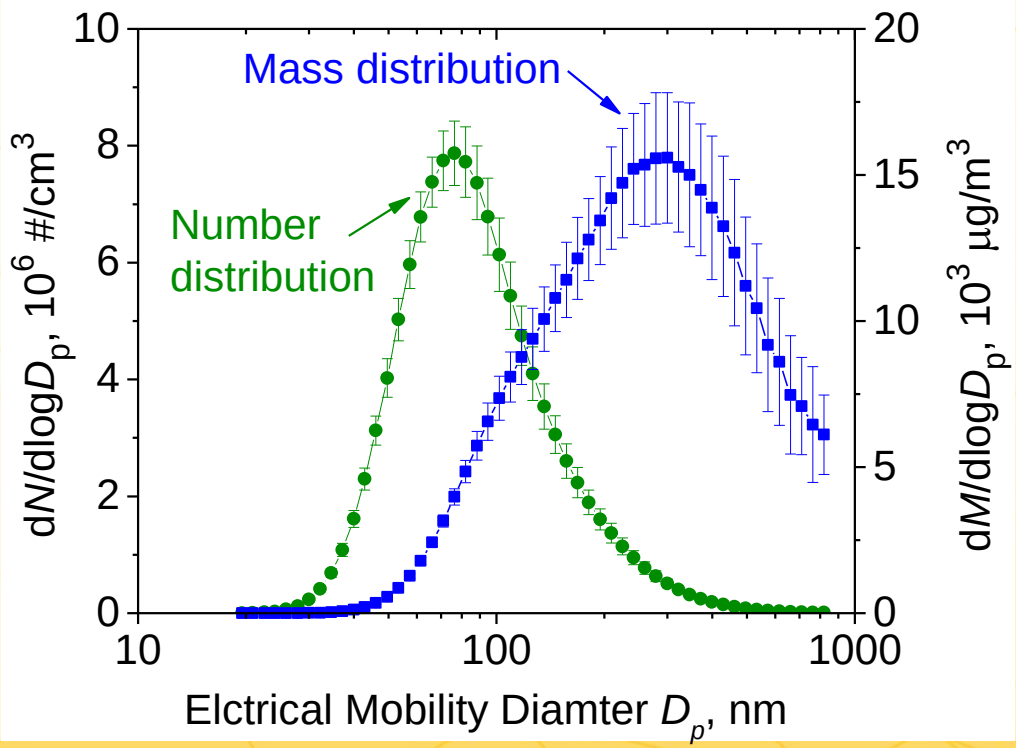


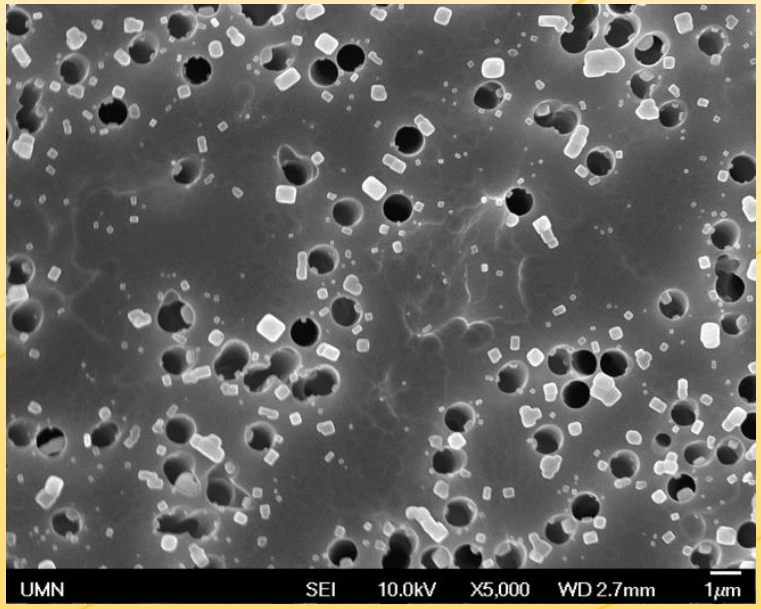
Temperature: 22°C

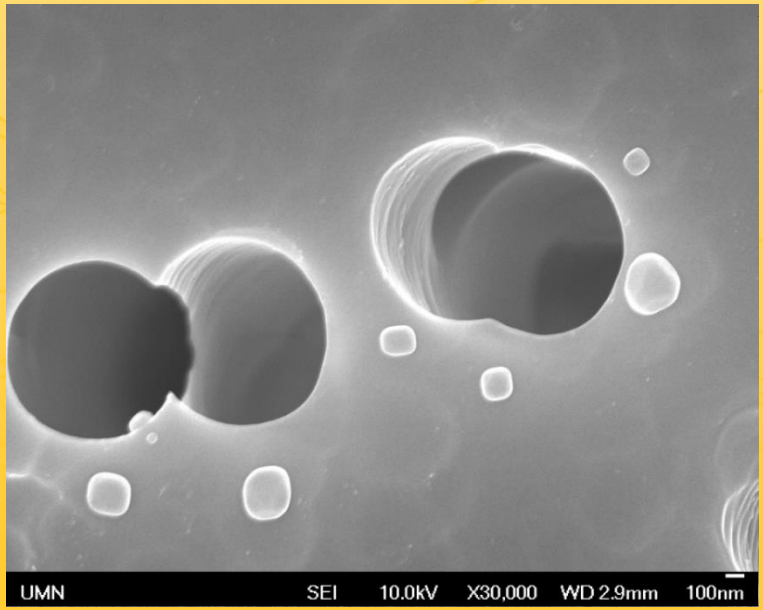
Face velocity: 25 cm/s

Final Δp: 300 Pa

Particle size distribution



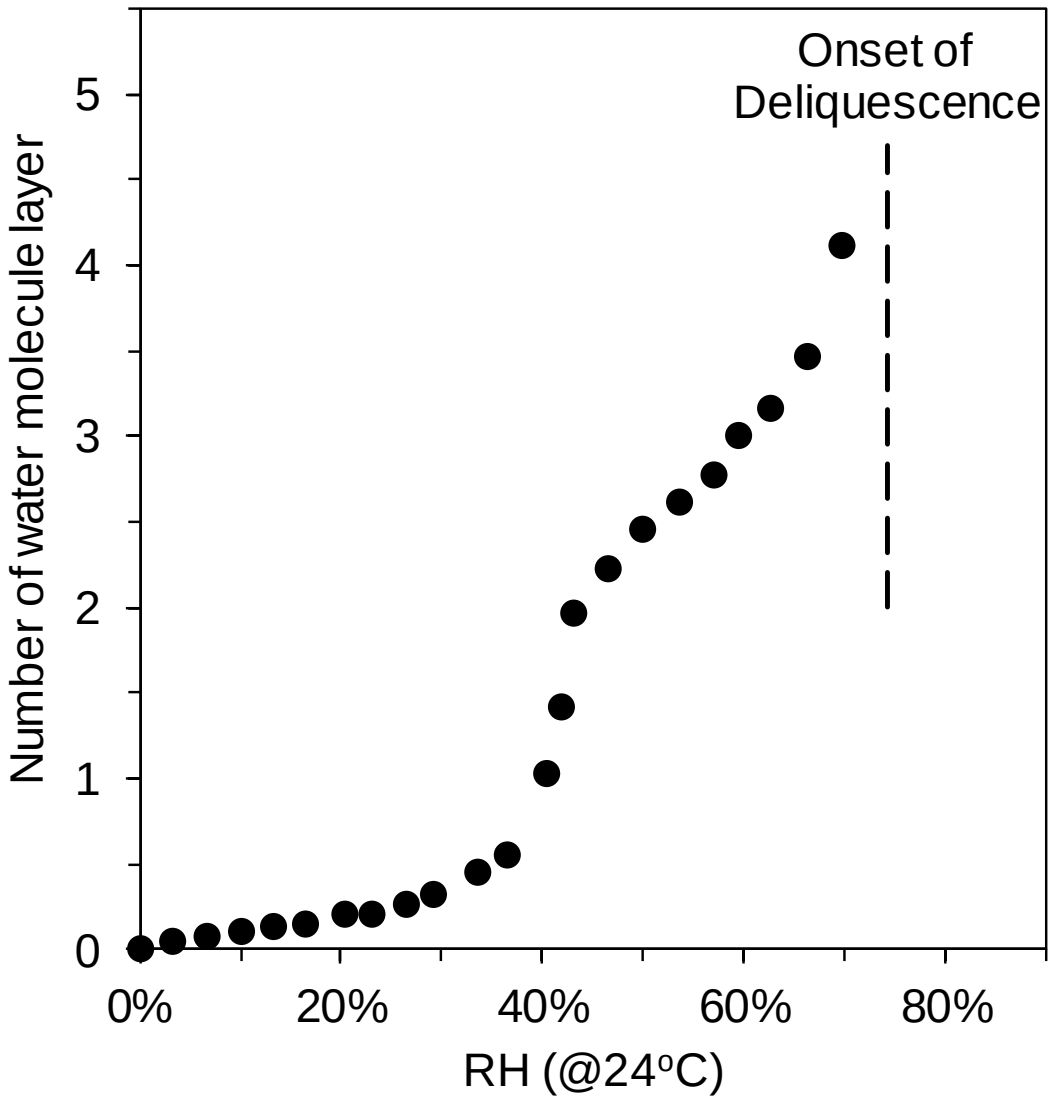




Count Median Diameter, nm	82.0±2.5
Mass Median Diameter, nm	259.5±14.4

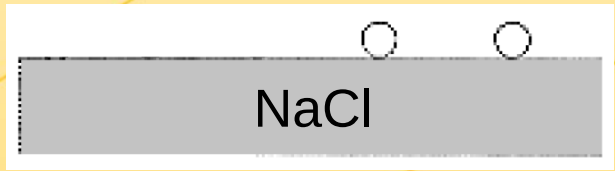
Mass concentration of loading particles:
7.0 ± 1 mg/m^3

Water on NaCl surface under different RH



An adsorption isotherm of water on NaCl

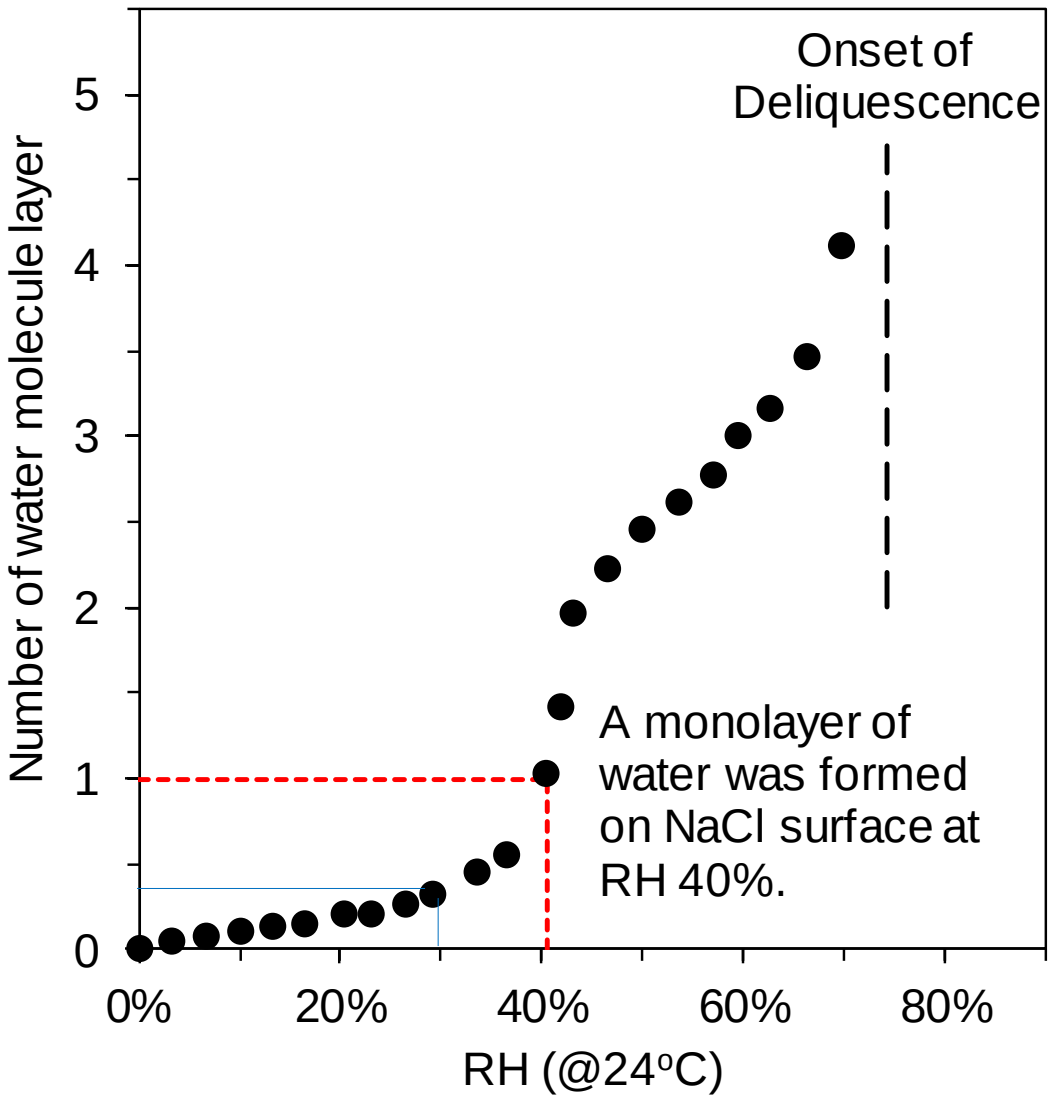
(1) RH < 10%



- Very sparse water adsorption, mainly on defect sites.
- NaCl surface is not significantly changed by water.

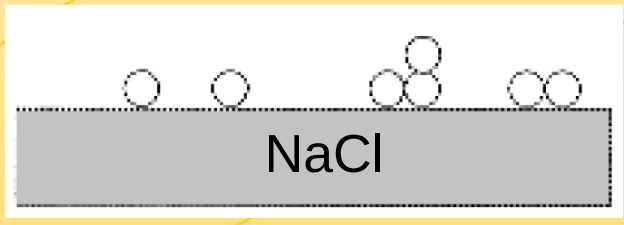
Ewing (2005)
Peters et al. (1997)
Woods et al. (2005)
Dai et al. (1997)
Luna et al. (1998)

Water on NaCl surface under different RH



An adsorption isotherm of water on NaCl

(2) RH 30%



- NaCl surface was covered by a fraction of a monolayer.

Ewing (2005)
Peters et al. (1997)
Woods et al. (2005)
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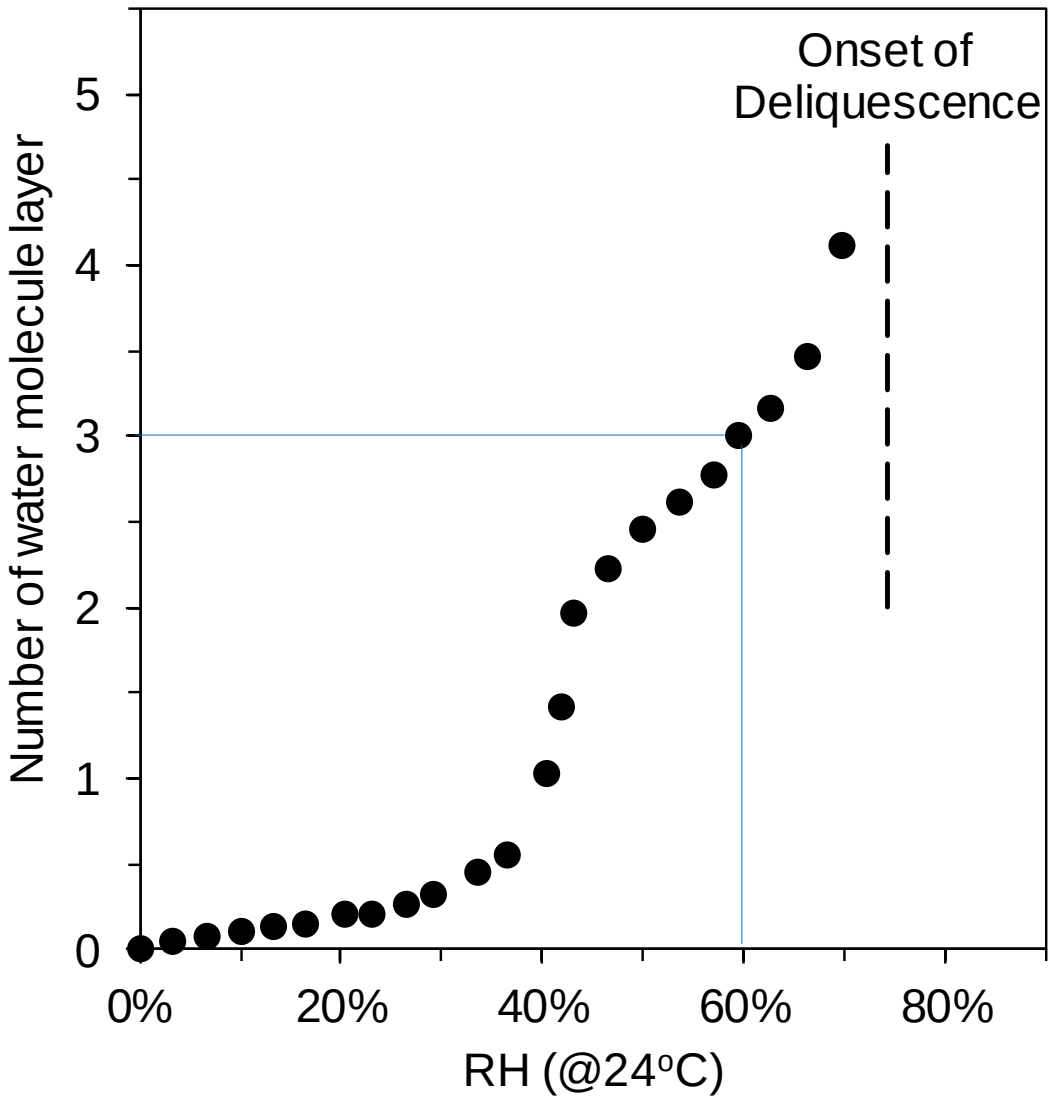
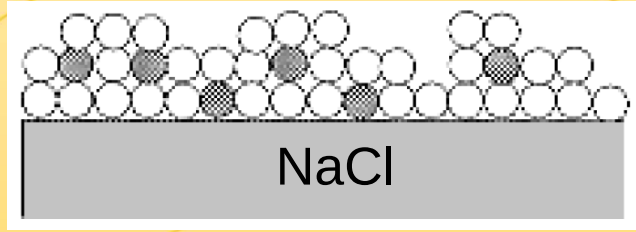
Water on NaCl surface under different RH



An adsorption isotherm of water on NaCl

(3) RH 60%



- NaCl surface have a liquidlike multilayer water film.

Ewing (2005)
Peters et al. (1997)
Woods et al. (2005)
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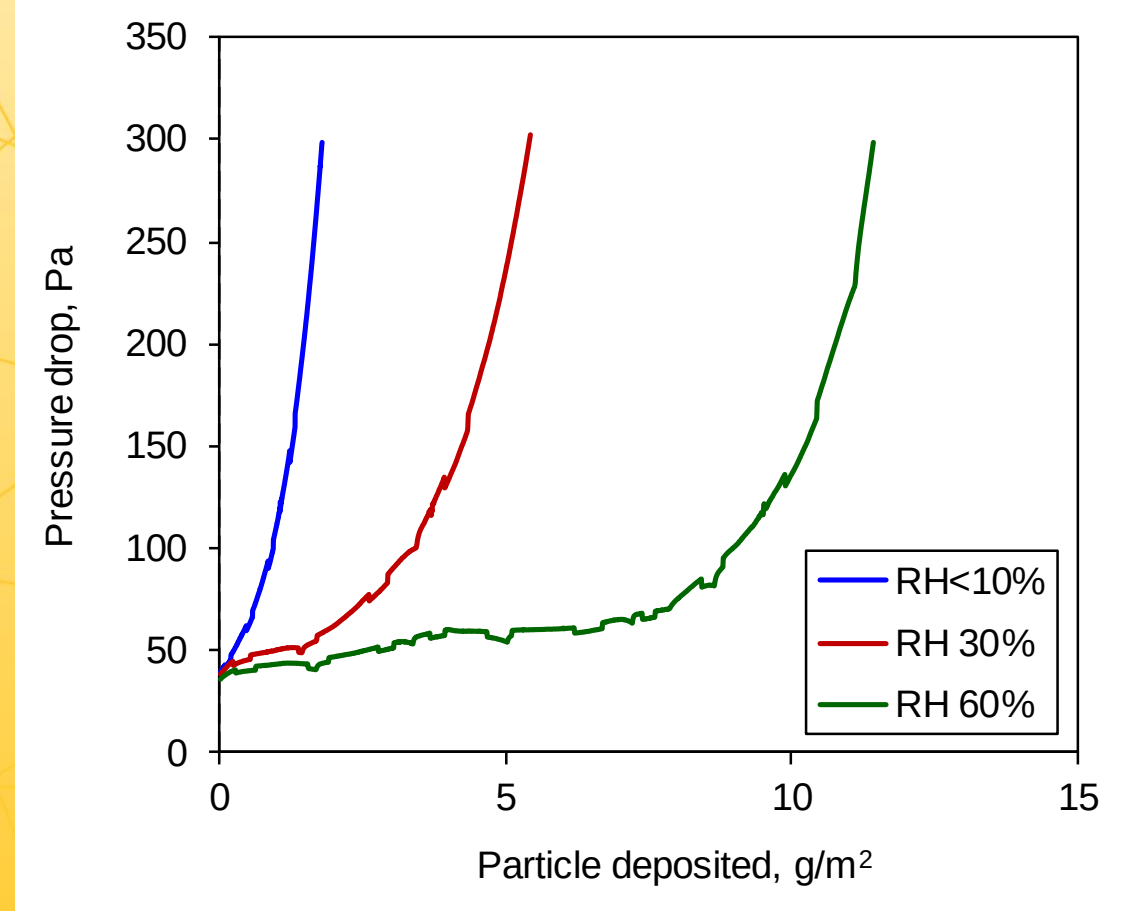
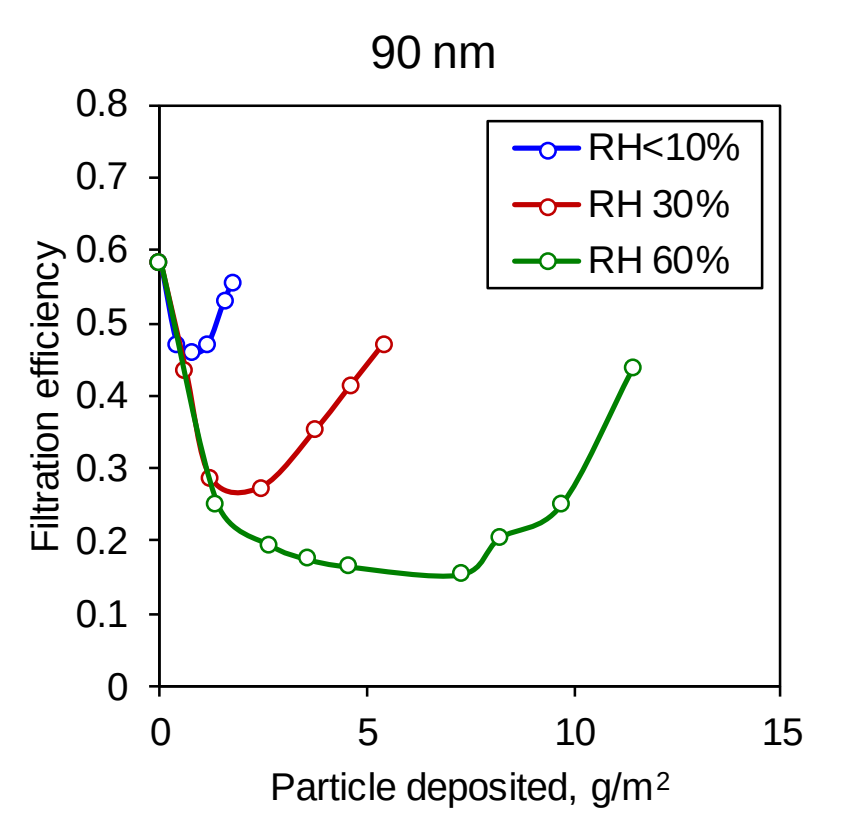
Pressure drop evolution under different RH

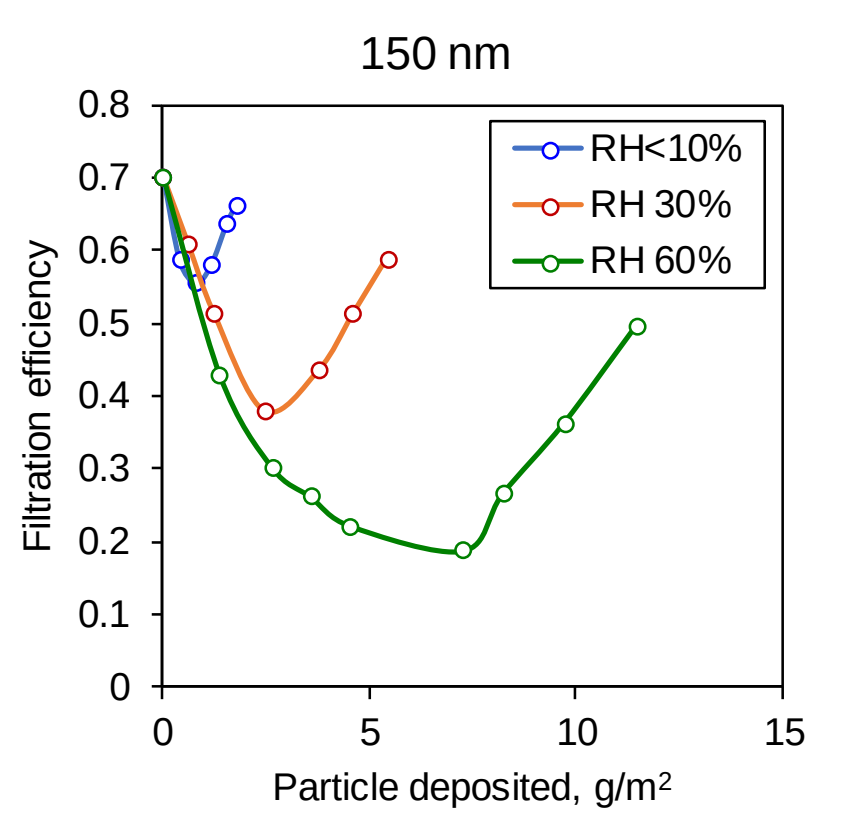


The pressure drop of electret media increased much slower under higher RH in the loading process.

Efficiency evolution under different RH

The efficiency of 90 nm and 150 nm particles in the loading process were evaluated.



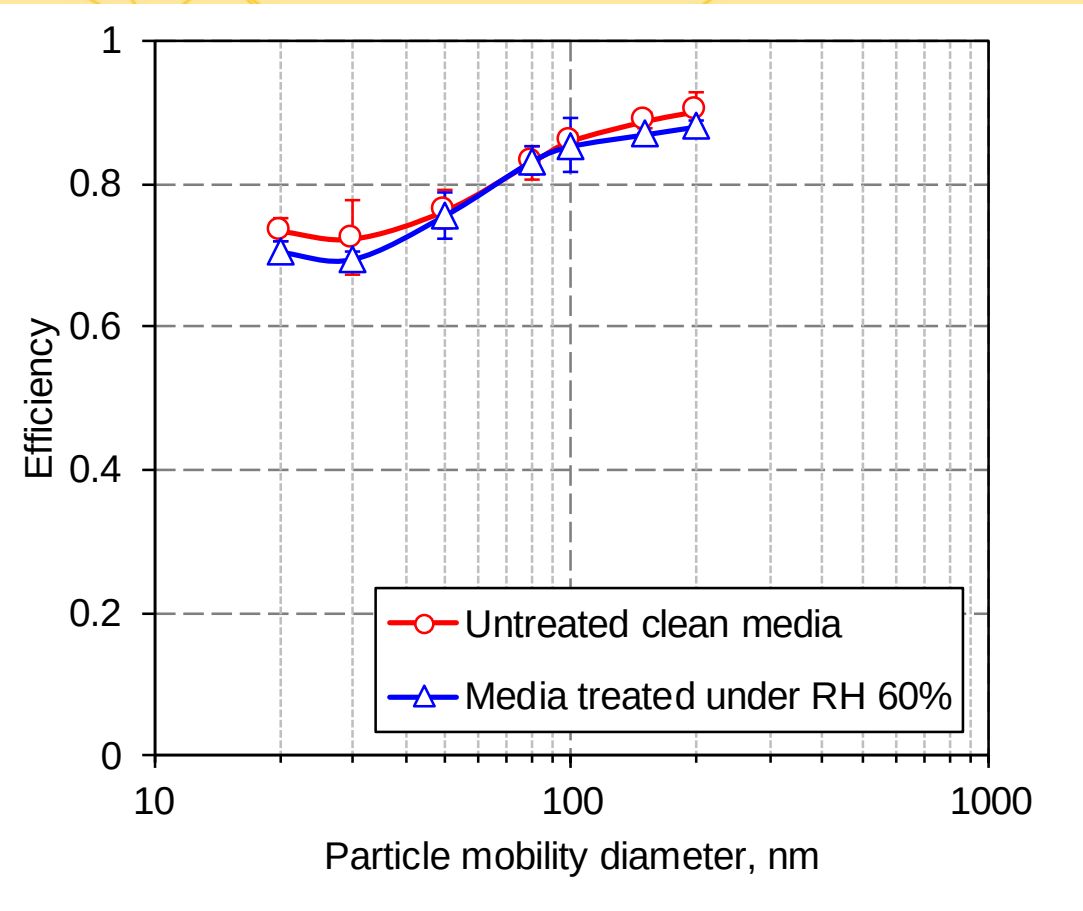


The minimum efficiency of loading was lower under higher RH.

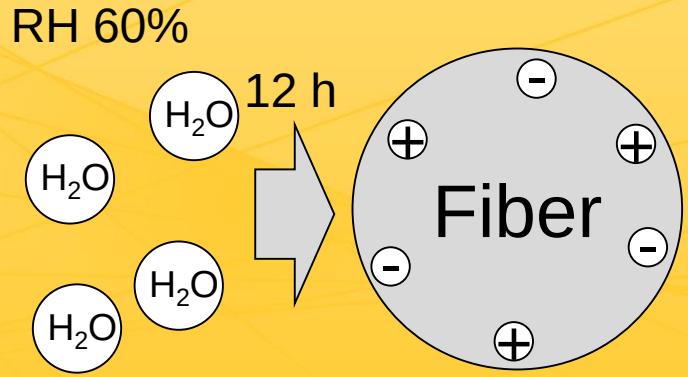
Two possible reasons of lower minimum efficiency:

- The water vapor molecule had an adverse effect on electrostatic effect of electret fiber.
- The water vapor molecule facilitated the collapse of particle dendrite built on fiber surface.

Impact of water vapor conditioning on clean electret media

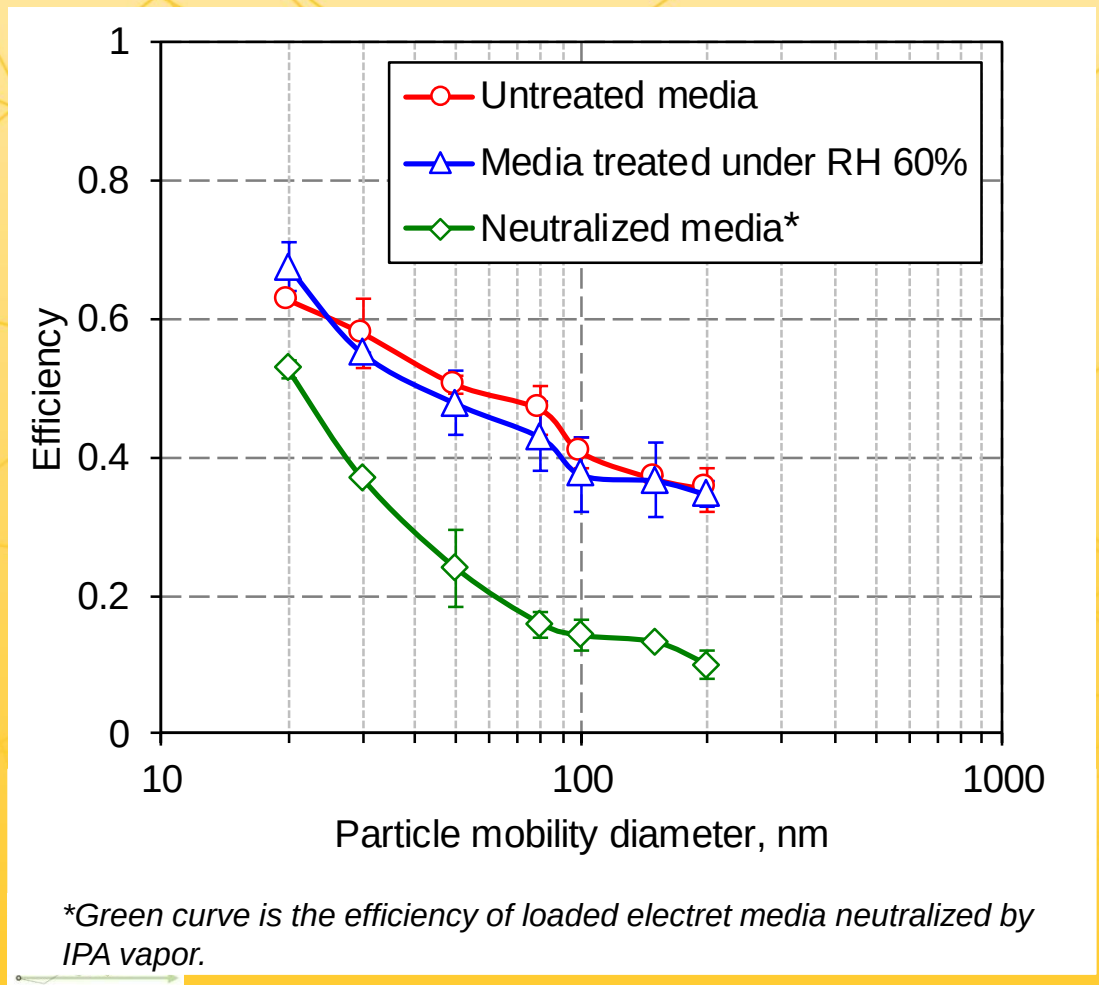


- Clean electret media were conditioned by airflow (RH 60%) for 12 hours.



Impact of water vapor conditioning on loaded electret media

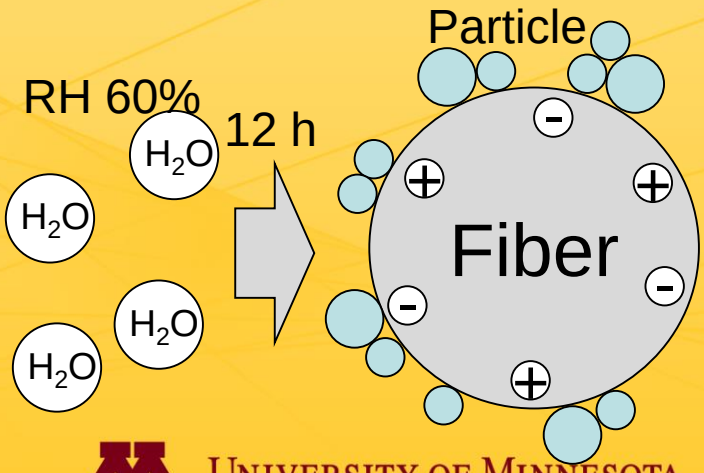
Electret media was loaded with 2 g/m^2 NaCl.



**Green curve is the efficiency of loaded electret media neutralized by IPA vapor.*

The water vapor molecule had few effect on electrostatic effect of electret fiber.

- No pressure drop change



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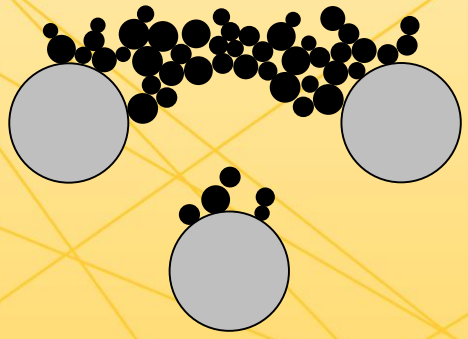
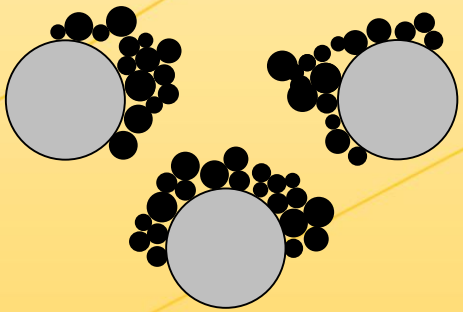
Hypothesis of the effect of relative humidity on dendrite collapse

Low relative humidity

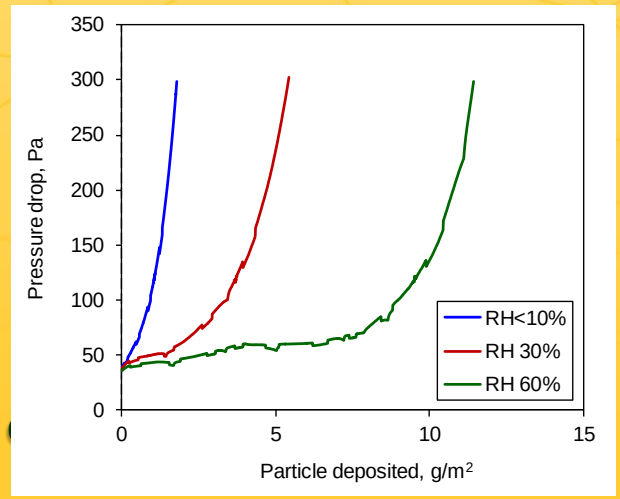


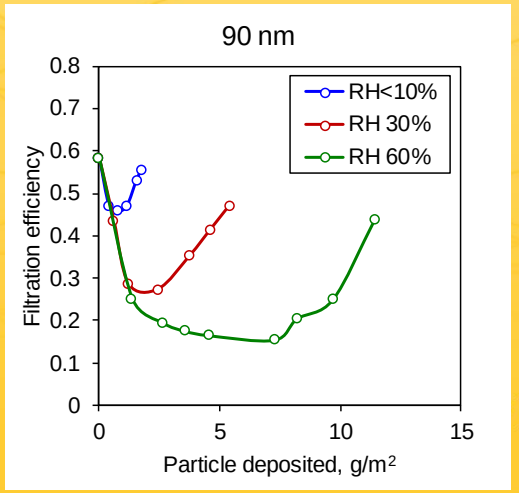
- More dendrites
- Higher efficiency
- Faster increase of Δp

High relative humidity



- Less dendrites
- Lower efficiency
- Slower increase of Δp





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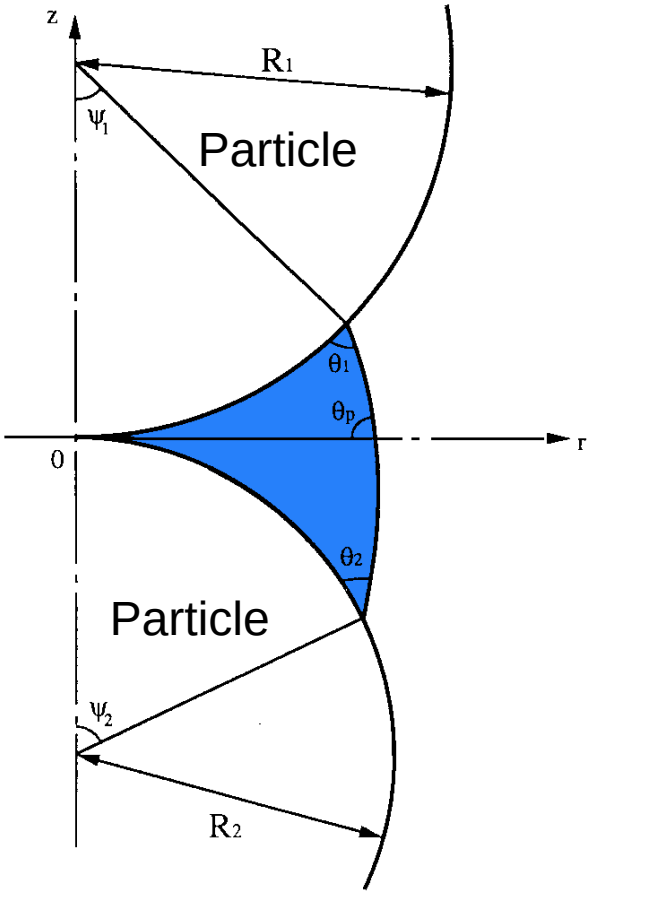
Dendrite collapse due to water condensation



- Theoretical calculations shown that at low RH, water vapor can condense at the region between two adhering particles. (Crouzet & Marlow, 1995)
- Condensed water caused dendrites to collapse due to capillary force on asymmetric part of the particles.
- Next step:
  Study the role of fiber charges on dendrite formation and collapse.

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Conclusion

- In the loading of electret media, the pressure drop increased much slower under higher RH.
- The minimum efficiency of loading was lower under higher RH.
- The difference of loading behavior under different RH could be due to collapse of particle dendrite.

Future work

- Develop a model of particle deposition on electret fiber under different RH.

Thank you!

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