Control of Nanoparticles by Filtration

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Introduction

Green Energy and Pollution Control Research Lab

The research areas of at this lab are **thermal engineering sciences** with applications to

- **green energy**, and
- **pollution control**
  - Particulate Matter
  - Acidic Gases (SO_2, NO_x, and CO_2)
  - The acidic gases are converted into secondary air pollutants (aerosol particles suspended in air)
  - Man made „engineered" nanoparticles
- Our goals in the area of nanofibers are:

1) to understand the nanoaerosol-nanofiber interfacial behavior
2) to develop cost-effective technologies for large scale nanofiber fabrication.

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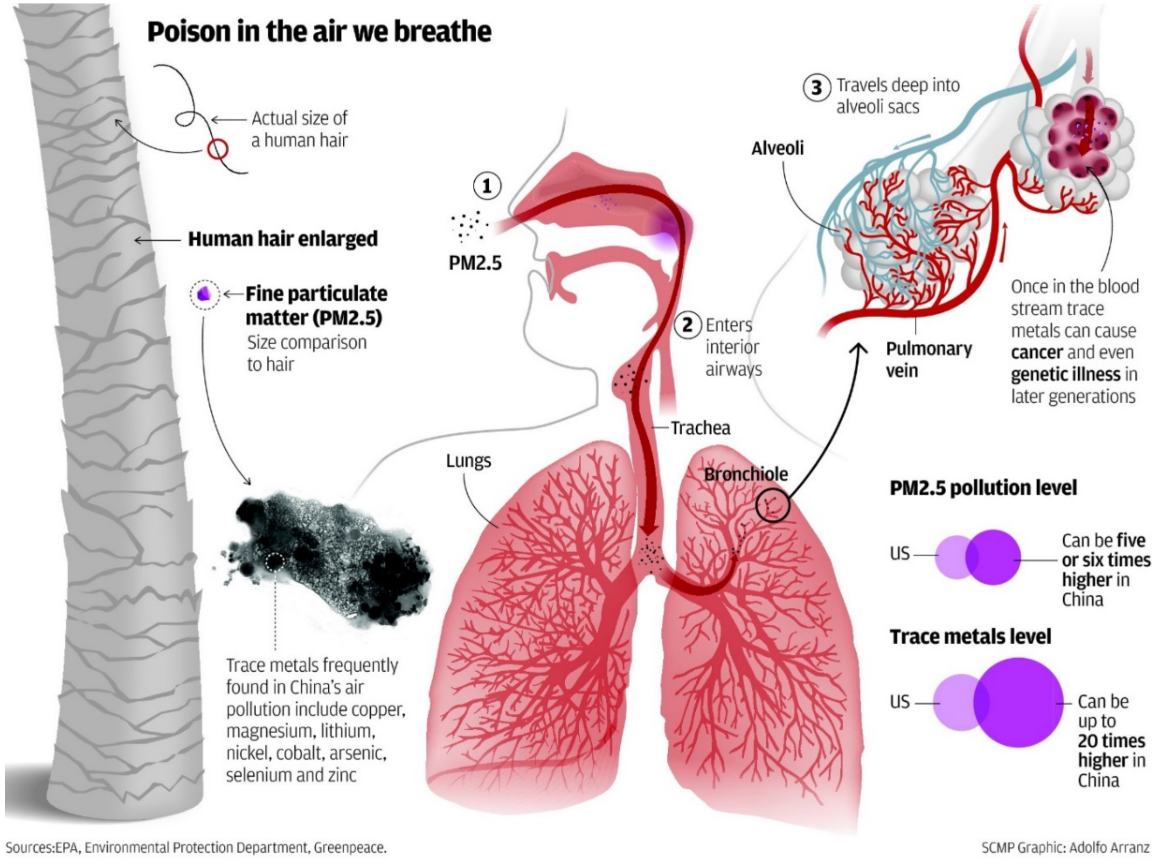
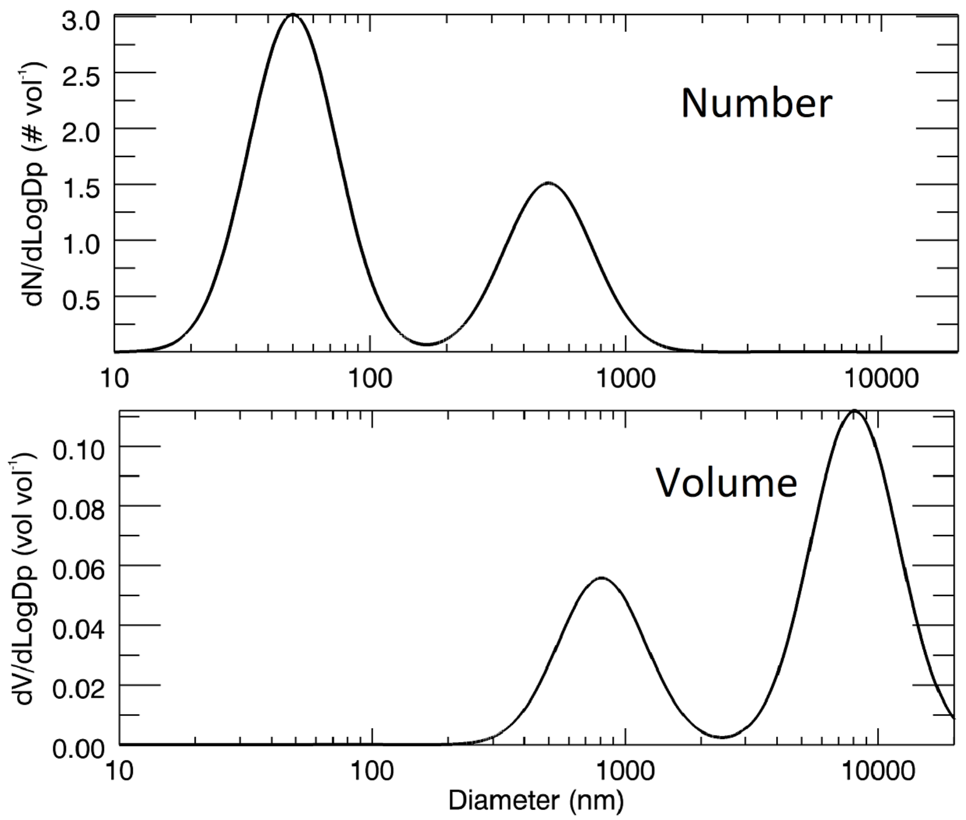
Health Impact of Nanoparticles

- Nanoparticles are particles sized smaller than 500 nm
- Can penetrate deep into the lungs





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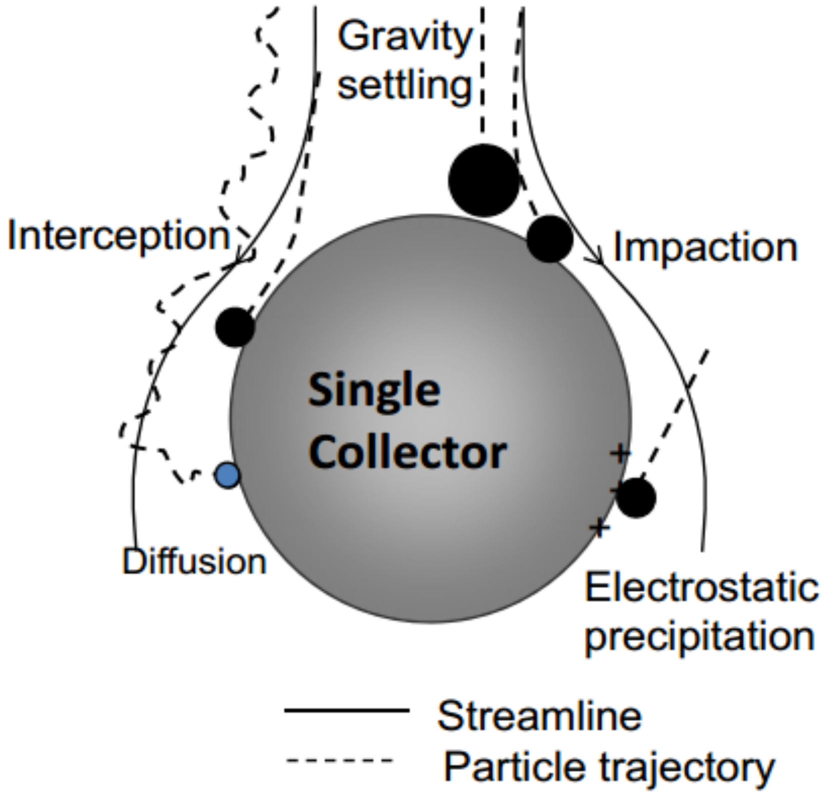
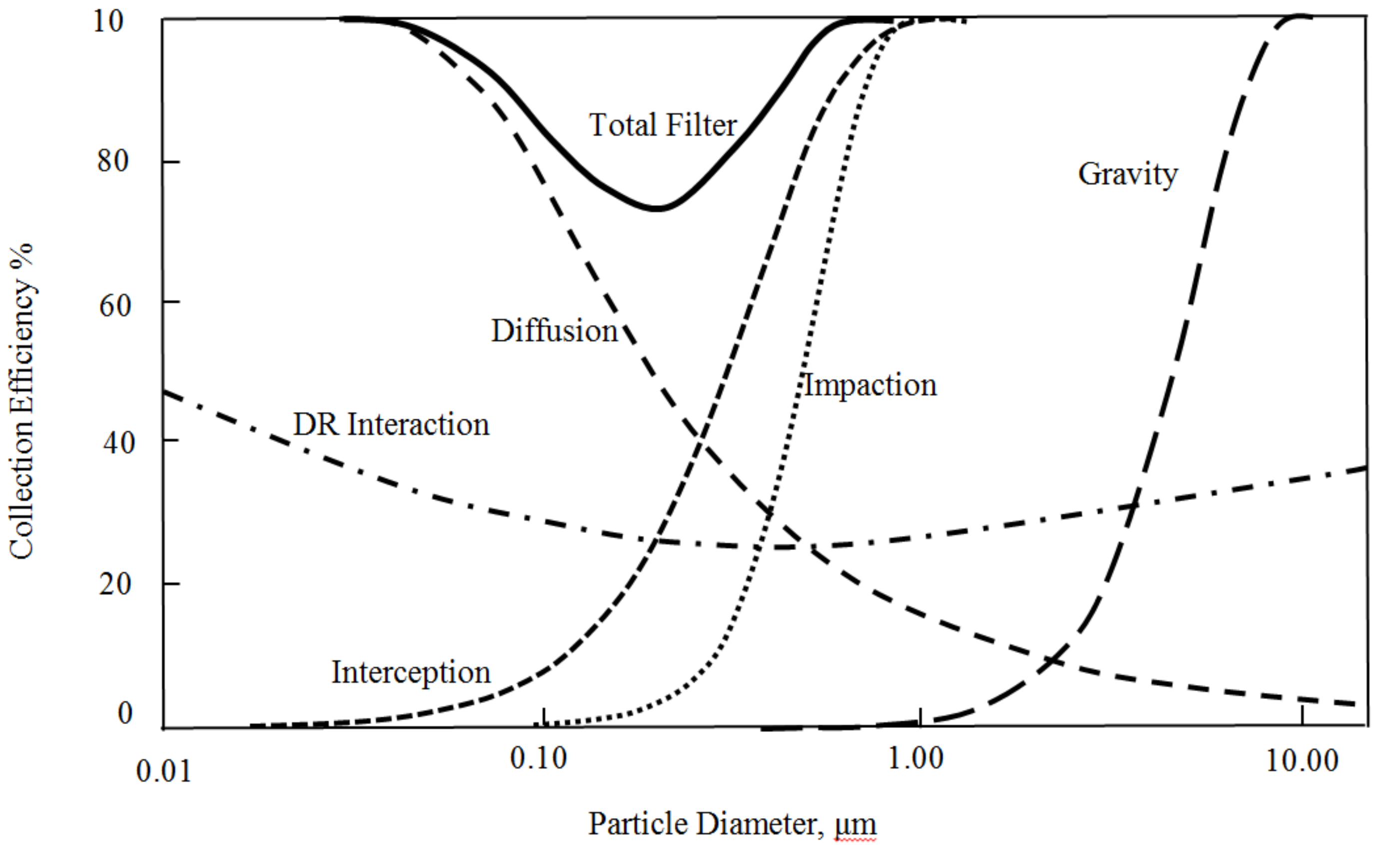
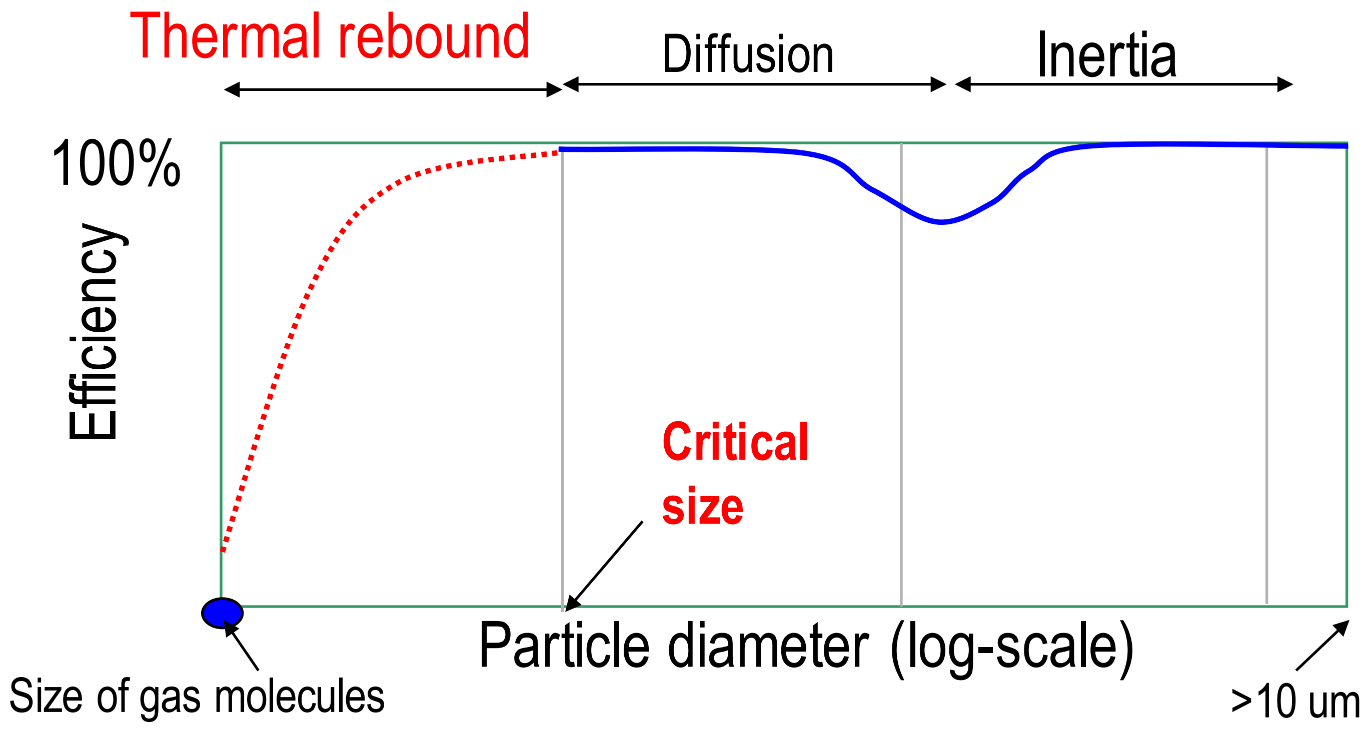
Classic Filtration Theory



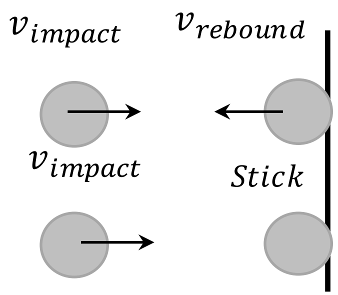


Thermal Rebound Theory

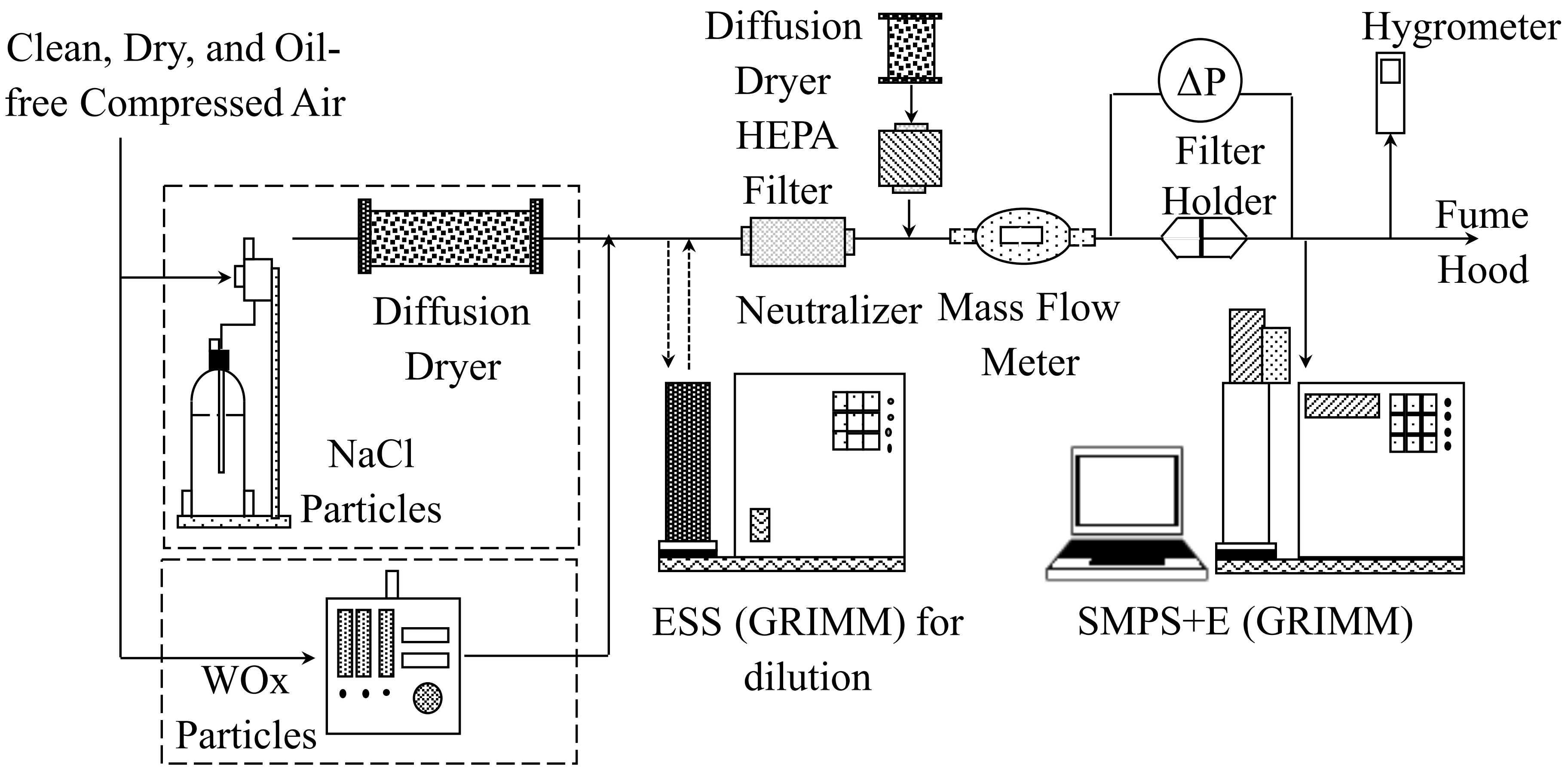


$v_{impact} > v_{critical}$

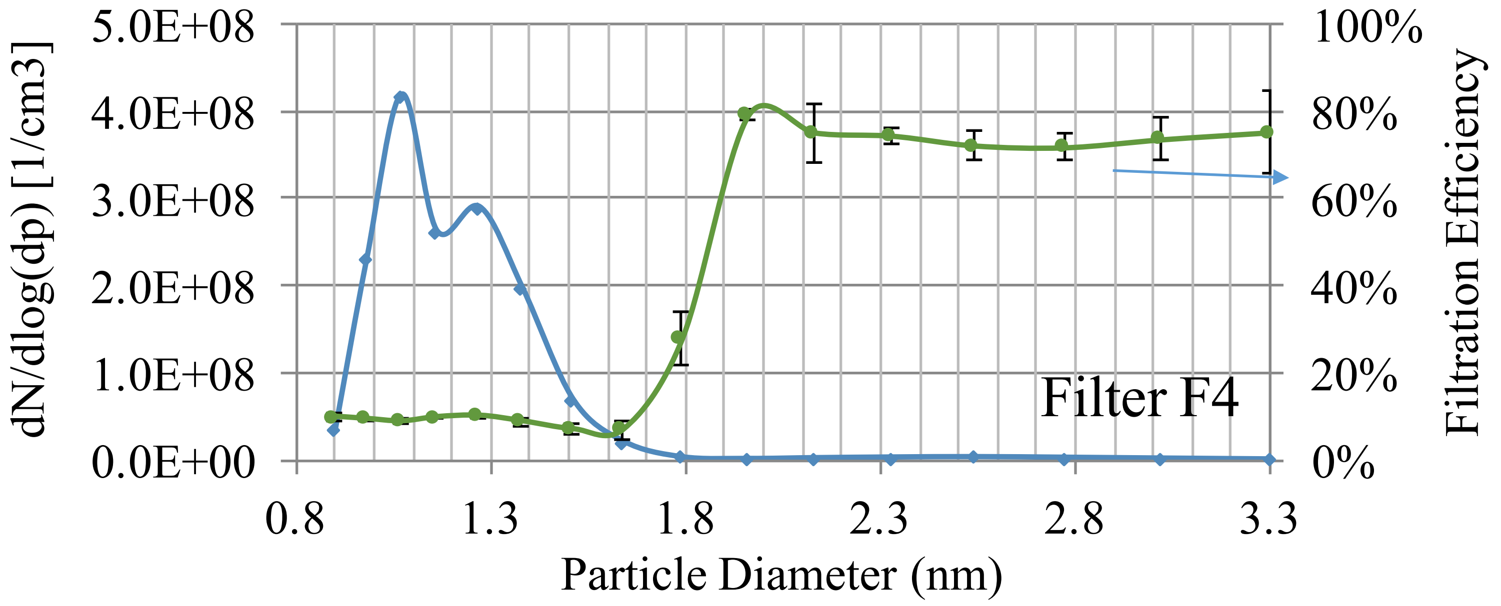
$v_{impact} < v_{critical}$



Filtration Testing Setup

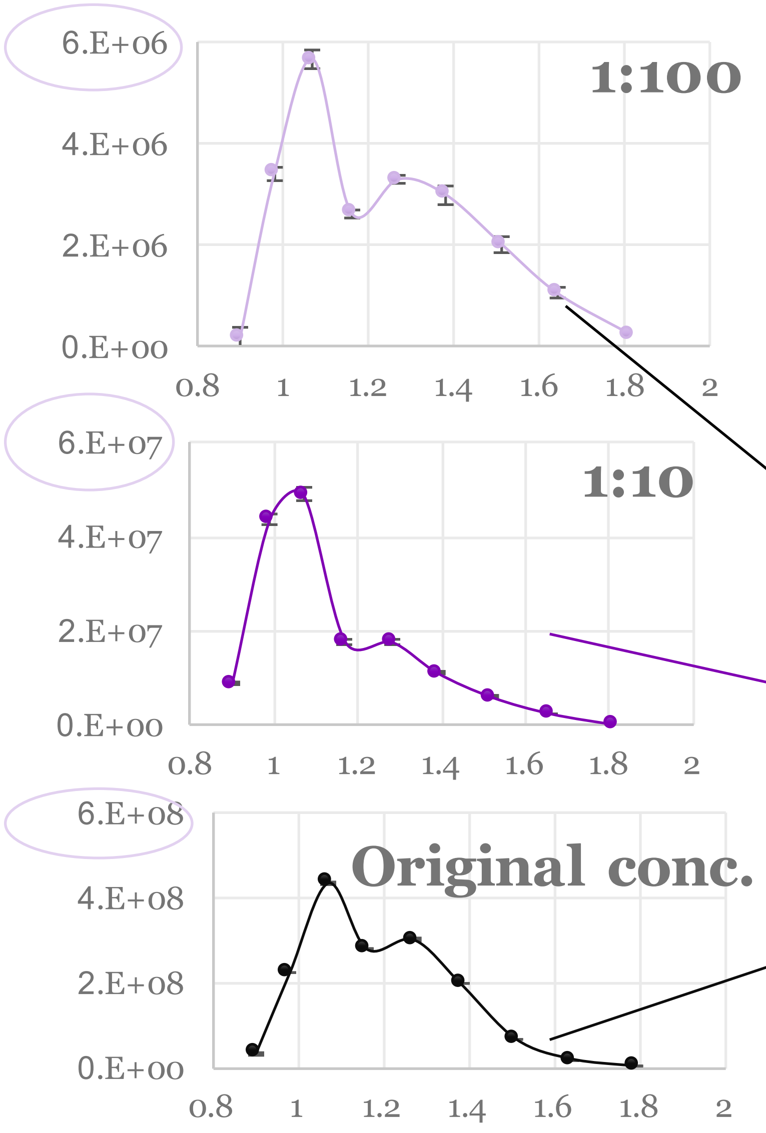


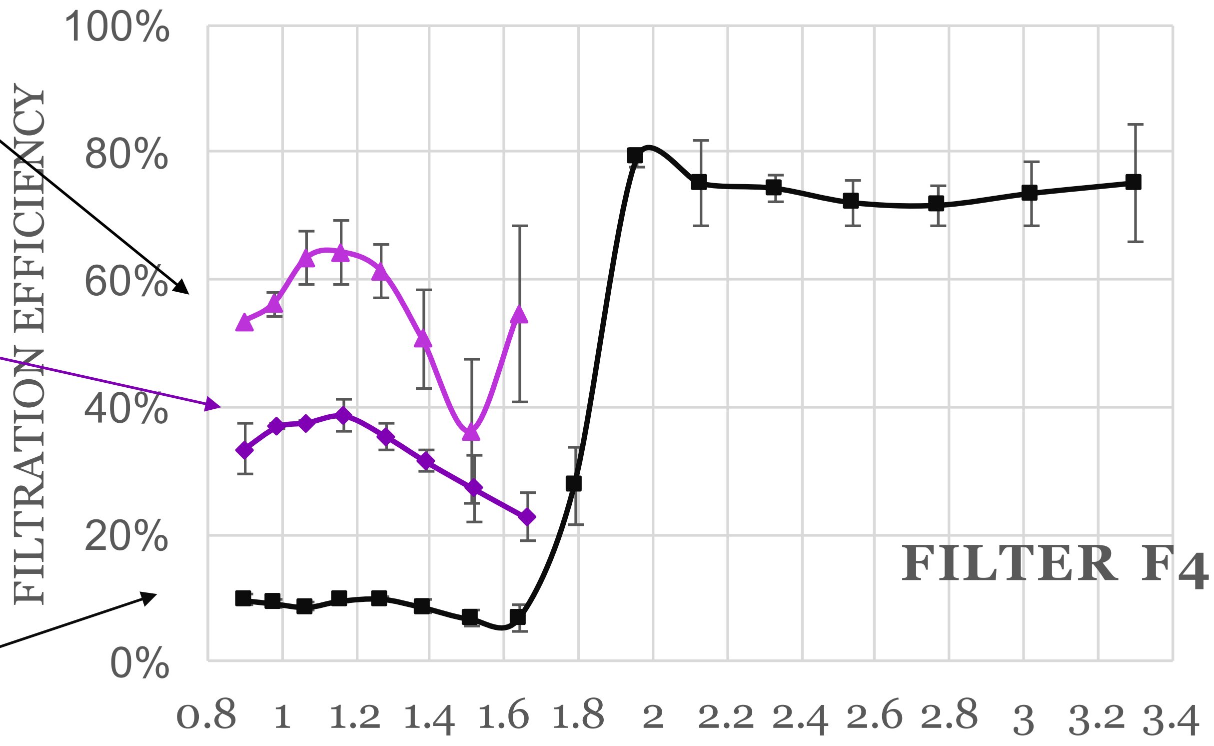
A Sharp Drop in Filtration Efficiency



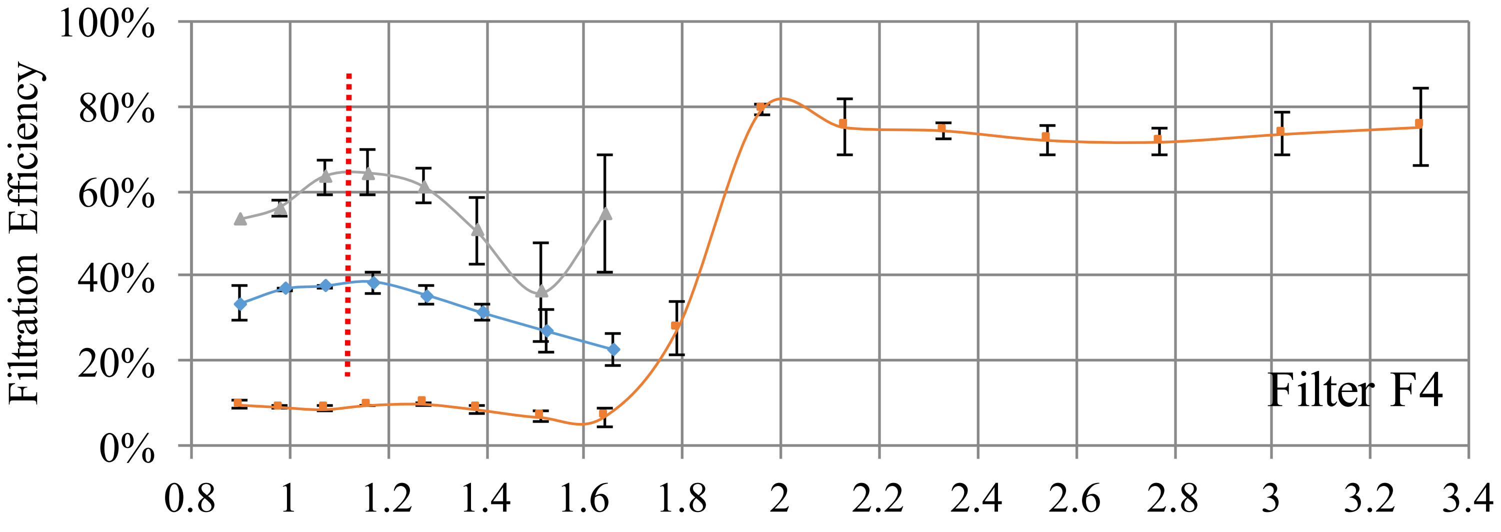
- Conventional filtration theory is no longer valid

Dependence on Particle Concentration





Thermal Rebound Present?



Thermal rebound for dp<1.07-1.17 nm?

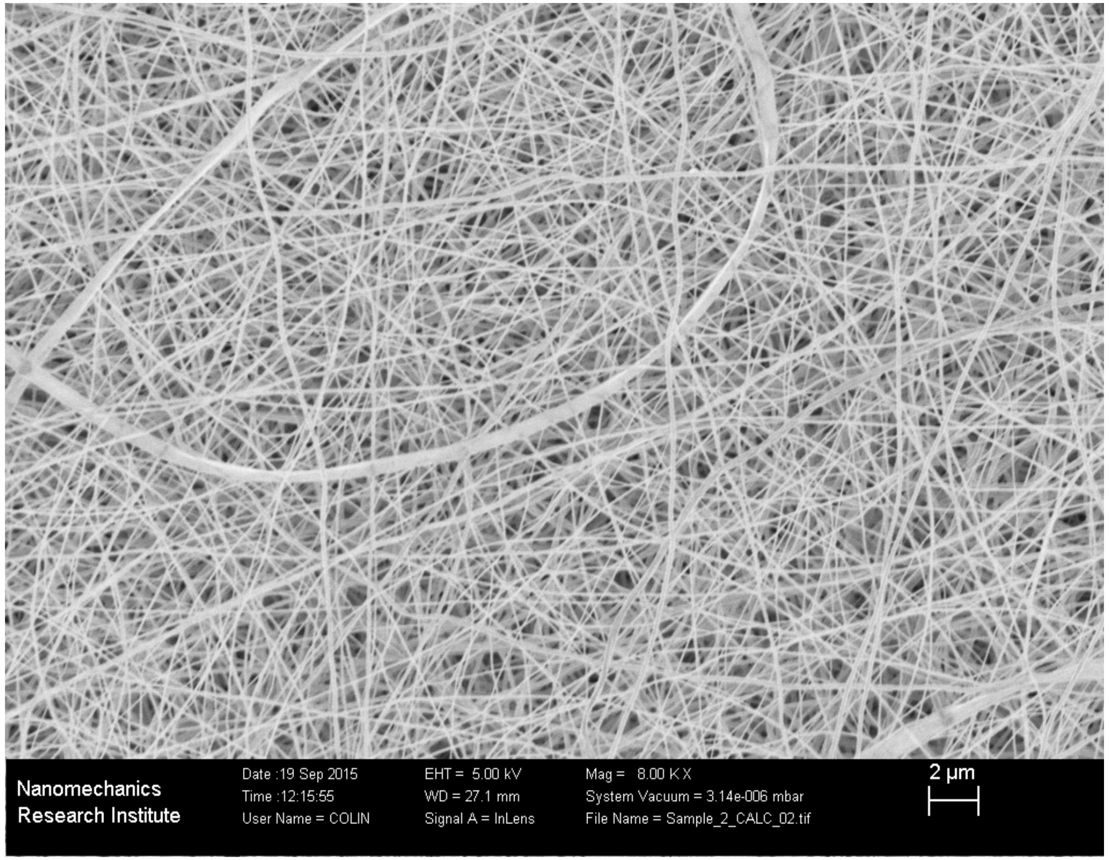
- Thermal rebound is more obvious at lower particle concentrations

Challenges of the Thermal Rebound

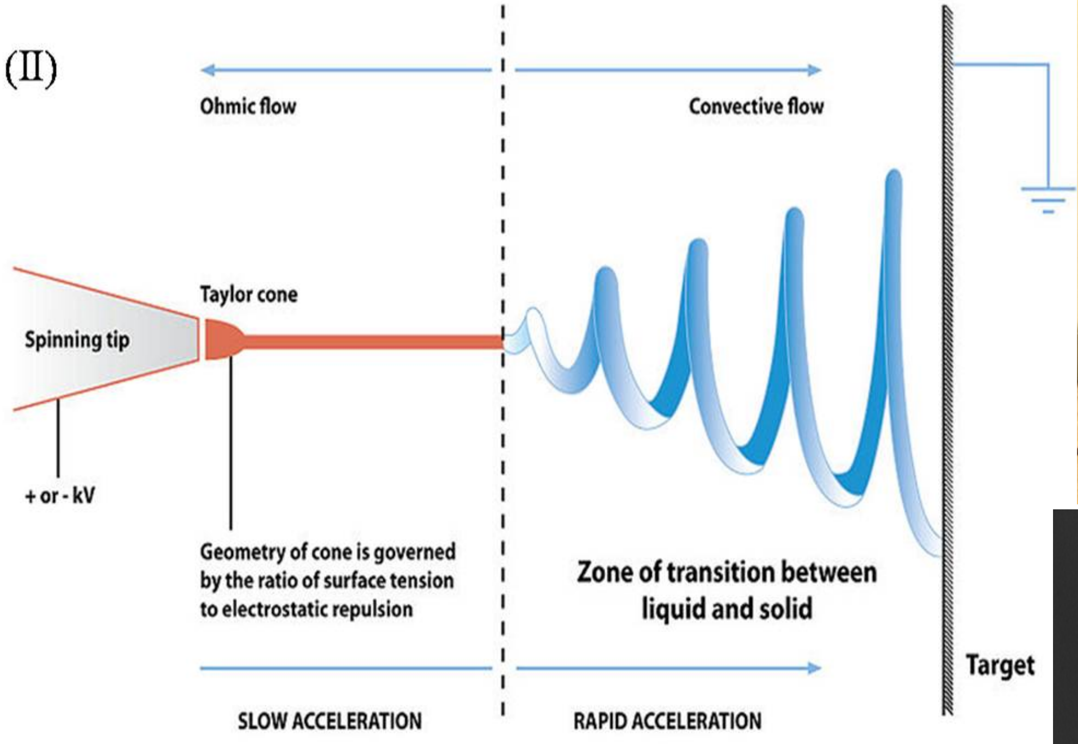
- Thermal Rebound occurs at **transition** from **molecular/nanoscale** interactions to **microscale** interactions
- Current models employ **Boltzmann** distribution, which applies for **ideal gases**
- Model is based on **mechanical properties of the particles**, which are challenging to determine
- Model requires exact values of **adhesion energy** between bodies, which typically are unknown
- Models assume **perpendicular impaction**, which is unlikely practical scenario
- **Agglomeration** of particles leading to bigger particles

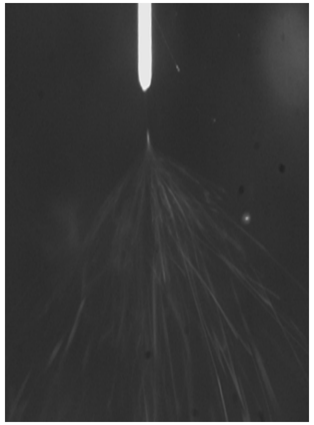
Nanofibrous Materials

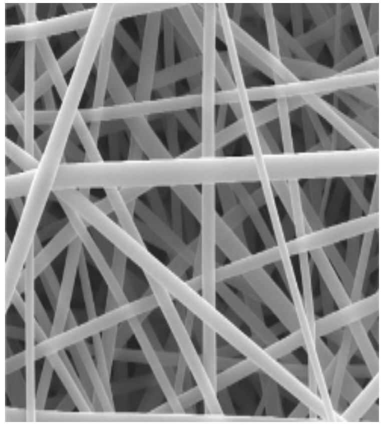
- **Large Surface to Volume Ratio**
- **Flexibility** in surface functionality
- Superior **mechanical performance**
- **Production** through:
  - Drawing
  - Template synthesis
  - Phase separation
  - **Electrospinning**



Electrospinning of Nanofibers







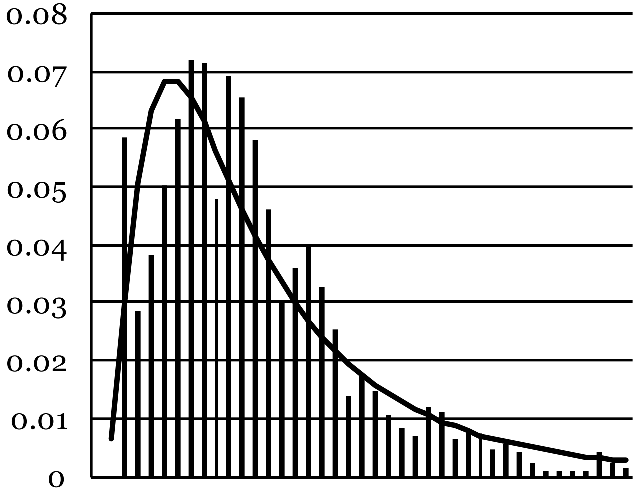
- **Polymer solution** drawn from a needle tip to a collector in an **electric field**
- Jet **elongates** due to random **whipping**
- Can produce fibers of a few **hundred Nanometers**

Parameters involed in Electrospinning

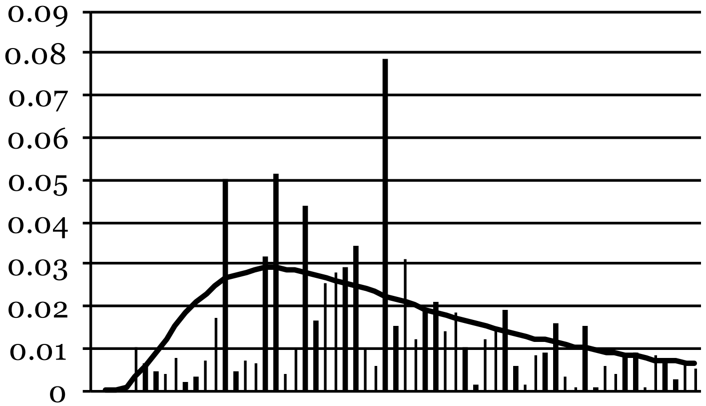
Processing Parameters		
Voltage	Distance	Needle Diameter
Feed Rate		
Environmental Conditions		
Temperature	Humidity	
Solution Distinct		
Elec. Conductivity	Viscosity	Surface Tension
Permittivity	Density	

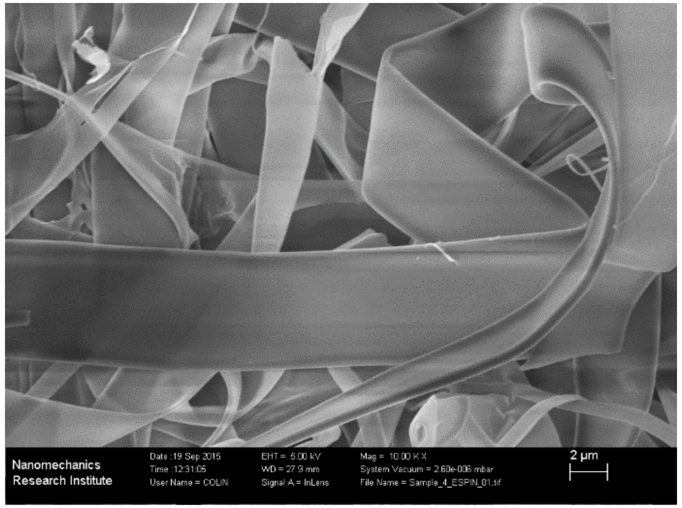
- Parameters interact with each other
- Each parameter has boundary conditions
- Number of Parameters makes Prediction challenging
- Quality effects are know, quantity effects are not

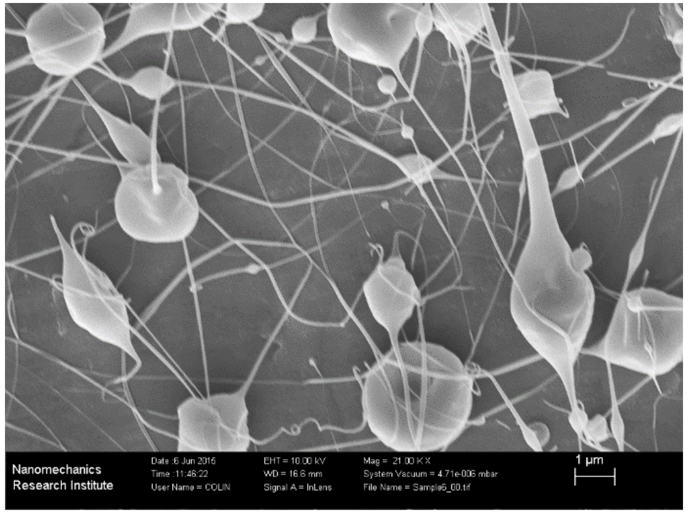
Knowledge Gap in Research in Electrospinning



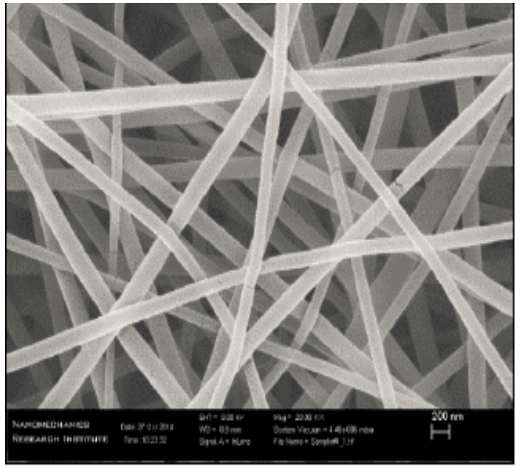
- Highly experimental
- **No model** for the process
- Incorrect setting can lead to: **dripping, clogging, spraying, beading, non-spherical fibers**
- **Low productivity** of electrospinning

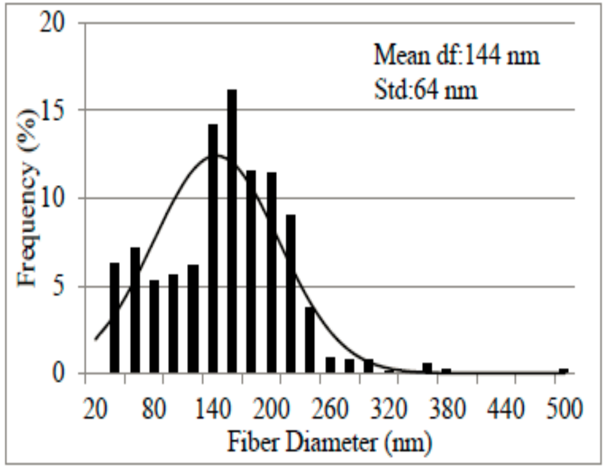


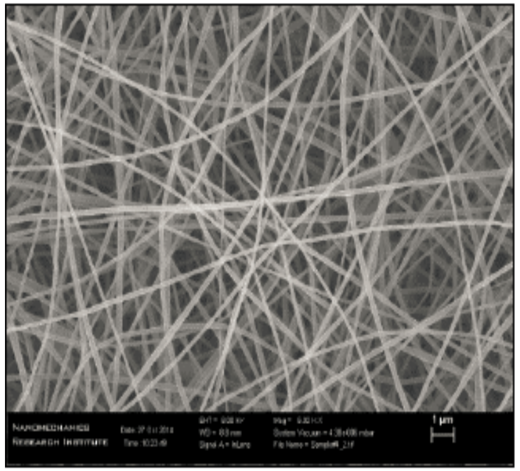


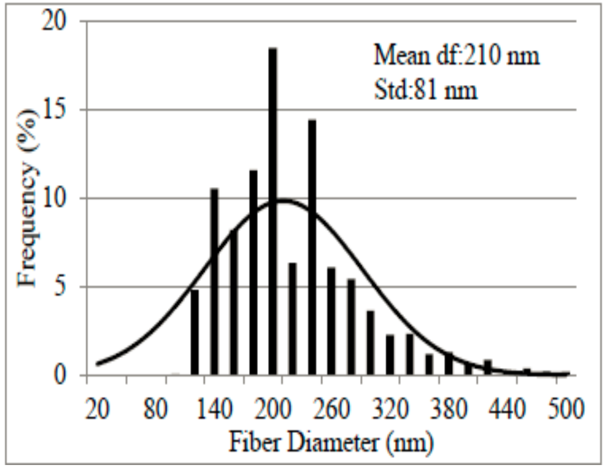


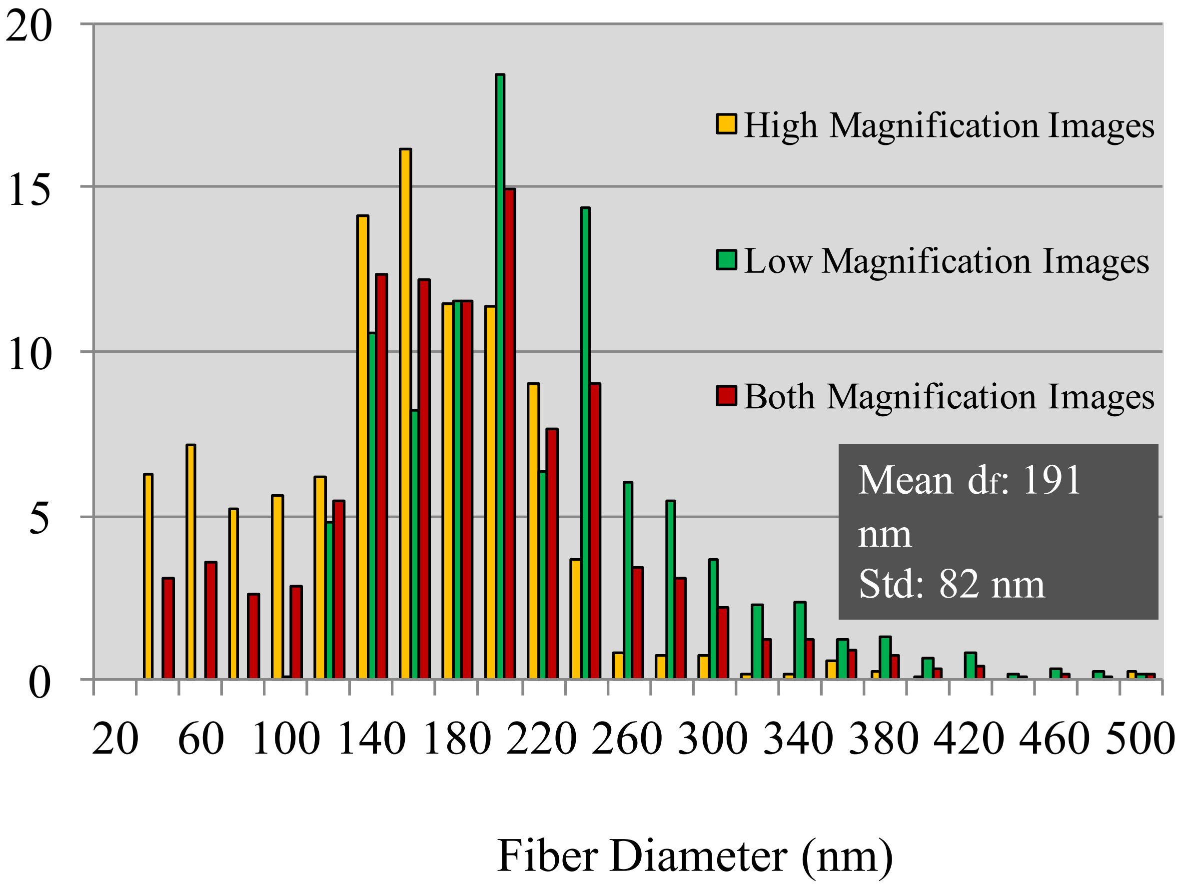
Determination of Fiber Size Distribution





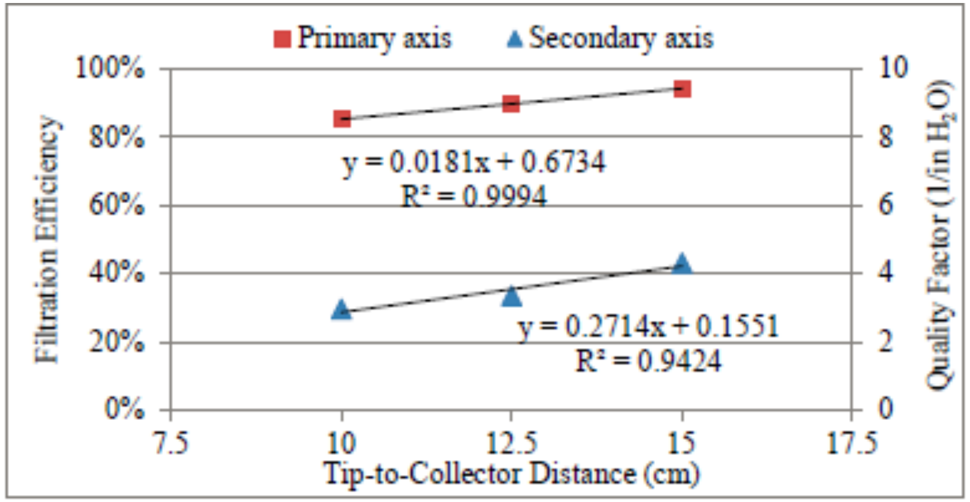




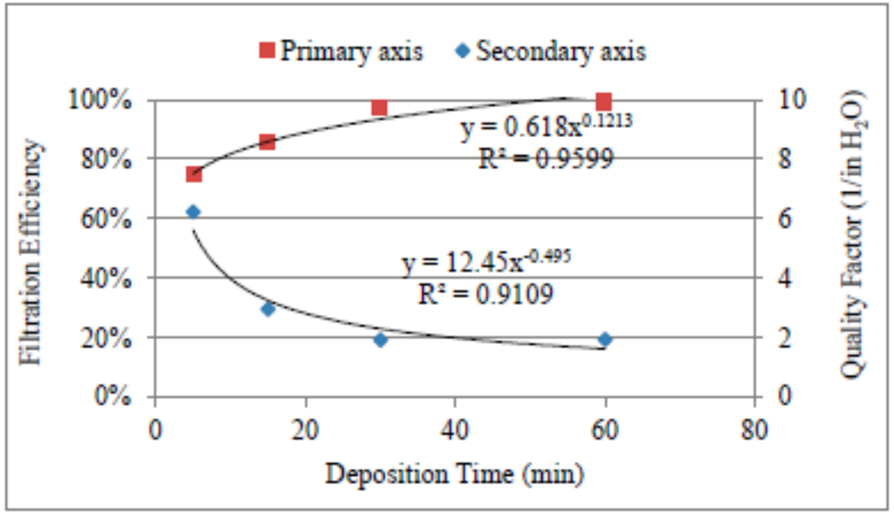


Effect of Single Parameters on Filtration Performance

Tip-to-collector distance



Deposition Time



$$Q_f = -\frac{\ln(1-\eta)}{\Delta P}$$

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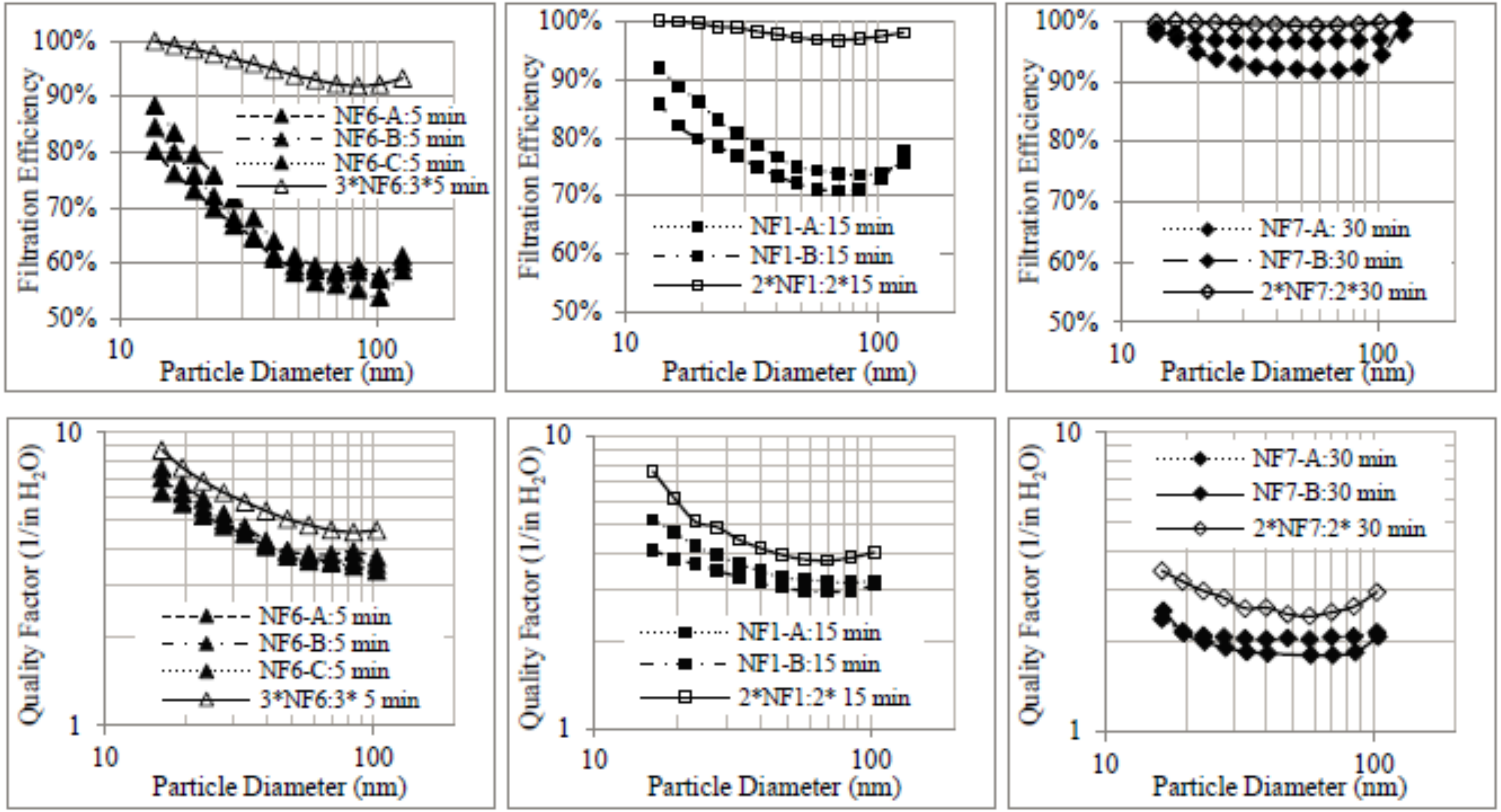
Effect of Layers



Conclusion and Summary

- Nanoparticles can be captured with nanofibrous materials
- Electrospinning is a versatile method of fiber production
- The electrospinning process is heavily depended on serval parameters
- Multiple thin nanofibrous layers are better than one thick layer
- The existing models for filtration of sub 10 nm particles are not modelling the actuals physical reality
- Thermal rebound as theory widely accepted, however it is challenging to proof

Acknowledgement

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THANK YOU FOR YOUR ATTENTION