Filtration: The effects of filters in air and liquid monitoring

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Background

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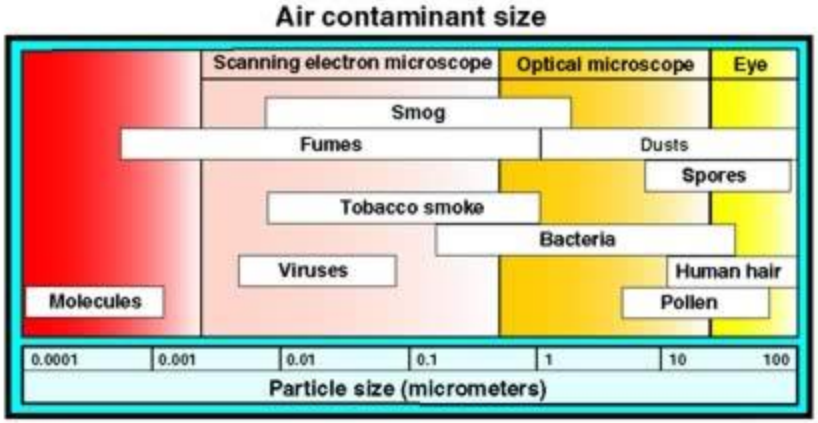
- Millipore was founded in 1954, first commercially available filter (MF- mixed cellulose ester)
- 1970- Clean Air Act introduced, 1971 National Ambient Air Quality Standard for Total Suspended Particles. Millipore sends scientists to Washington to help draft some of the first methods for particle/contamination monitoring for air/water/soil testing



Courtesy of www.cdc.gov

Filter Types

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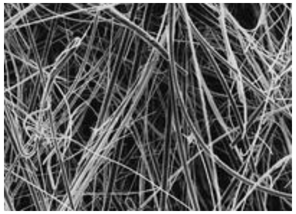
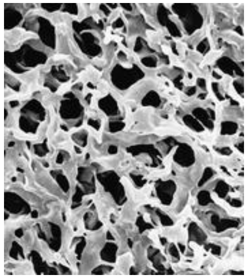
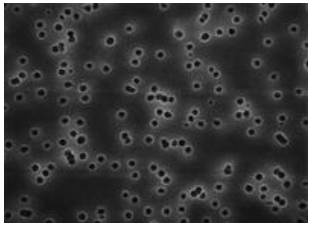
- Depth Filters
  - Matrix of randomly oriented fibers pressed together to form flow channels
  - Nominally rated, no exact pore size
  - Large particle loading capacity, excellent flow rates
  - Glass fiber, polypropylene



- Screen Filters
  - “Absolute” pore size ratings, surface retention
  - Rigid, uniform mesh of material
  - PTFE, PVDF, MCE



- Track Etched Filters
  - Pores are generated by the film exposure to a beam of accelerated Cr^{6+} ions, then placed in a bath of NaOH
  - Clean, cylindrical pores of a uniform diameter
  - Smooth surface



Filter materials and applications

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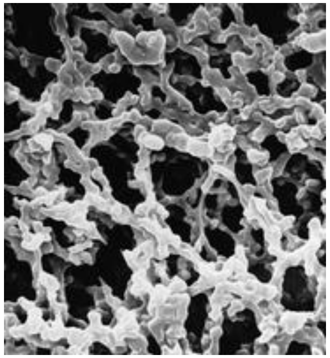
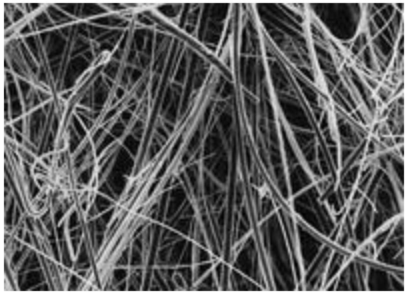
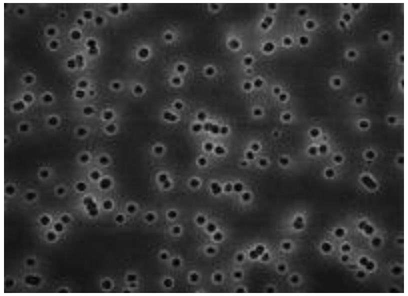
- MF (mixed cellulose ester)
  - First filter to market
  - Used extensively for microorganism collection
  - Can be dissolved for analytical purposes
  - Clean room/garment monitoring
  - Microbiological monitoring
  - Asbestos testing
  - Metals
- Glass fiber (borosillicate microfiber)
  - Large particle load
  - Able to be ashed for volitiles
  - Carbon free
- Polycarbonate
  - Transparent filter for microscopy
  - Smallest pore size distribution of any filter
  - Track etched membrane







Filter Materials and Applications

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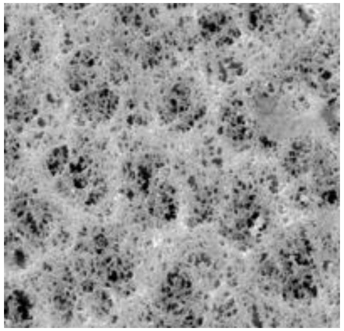
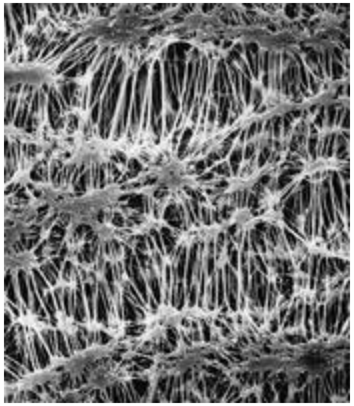
- PVC
  - Medical grade
  - Silica, carbon black, quartz
  - Zinc, lead, etc.



- PTFE (Fluoropore, Mitex)
  - Hydrophobic membrane
  - Very low extractables, inert
  - Alpha particle monitoring
  - Benzene, sulfides, alkalines



- Other materials available: Polycarbonate, silver, nylon, PVC, quartz
- Millipore can also supply materials in rolls or special cut sizes

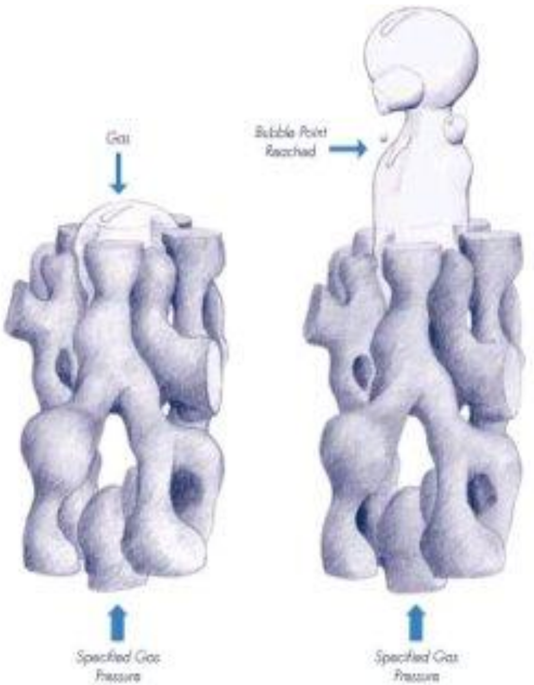
How is Pore Size Measured?

- Bubble Point

Bubble point is based on the fact that liquid is held in the pores of the filter by surface tension and capillary forces. The minimum pressure required to force liquid out of the pores is a measure of the pore diameter

Bubble point formula: $P = \frac{4k \ \cos\theta}{d} \sigma$

where:
P = bubble point pressure
d = pore diameter
k = shape correction factor
cos = liquid-solid contact angle
= surface tension



Air vs Liquid filtration

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- Pore sizes of filters are measure in liquid. Ratings for air are usually described in retention sizes, ie DOP >99%
- Liquid filtration is affected by the buffer system
  - pH, salt concentration, biological components, particle size dispersion, filter compatibility
- Air filtration is much more complex due to electrostatic effects
  - Any filter can be used with air but the results can vary depending on the material of construction and sampling conditions
- There is no true correlation between air filtration and liquid filtration, each must be quantified independently, even if you are looking for the same contaminant

Mechanisms of Air Filtration

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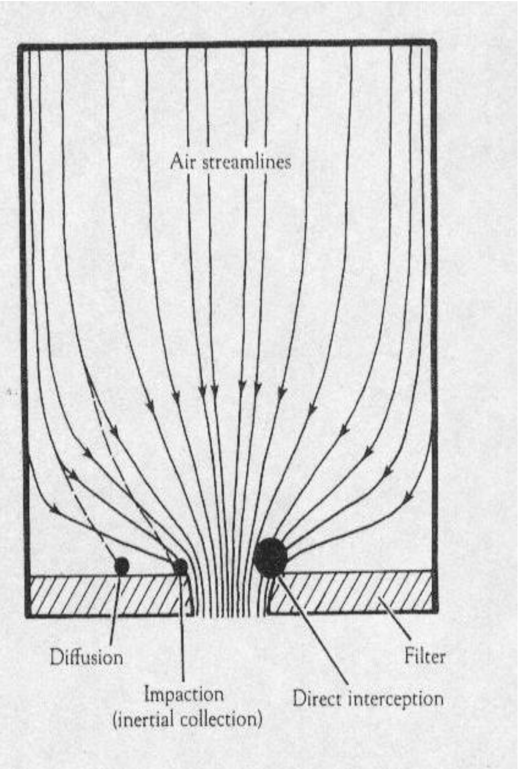
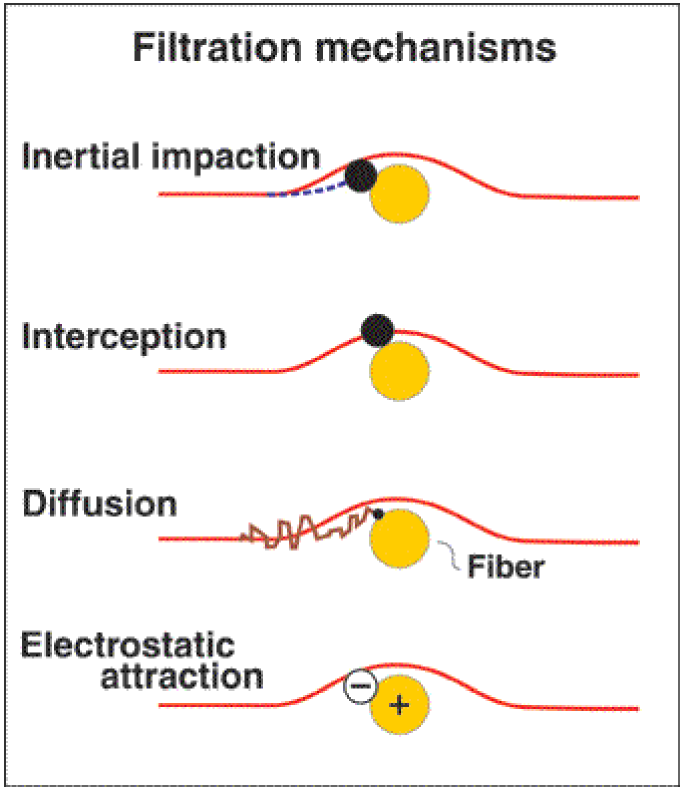
Particle retention in air is affected by several factors unlike liquid which tends to rely heavily on pore size for capture efficiency

- **Impaction-** Particles (especially around 1 um) do not flow precisely with the air stream, and will tend to move in straight lines when the air streams bend, impacting the surface of the filter





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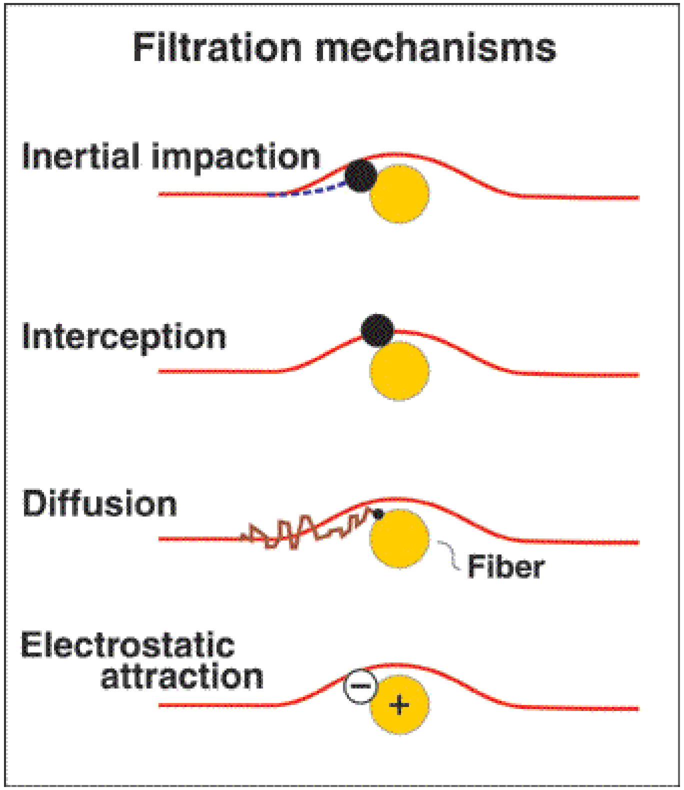
- **Direct Interception-** (as with liquid)
  - Particles larger than the pore size of the filter are removed
  - Particles with a radius which is an appreciable fraction of the pore size radius get removed- this is because particles of this size moving with the air stream have a large probability of touching the filter surface.
- **Diffusion-** particles exhibit Brownian movement and diffuse in response to concentration gradients. Since at the surface of the filter the concentration of particles is initially zero, a concentration gradient is set up leading to the movement of particles out of the air stream and onto the filter surface. Diffusion is favored by low air flow velocities and high concentration gradients. Only particles less than 0.1um will be removed to an appreciable extent by diffusion.



Particle Retention in Air Typical Capture Profile

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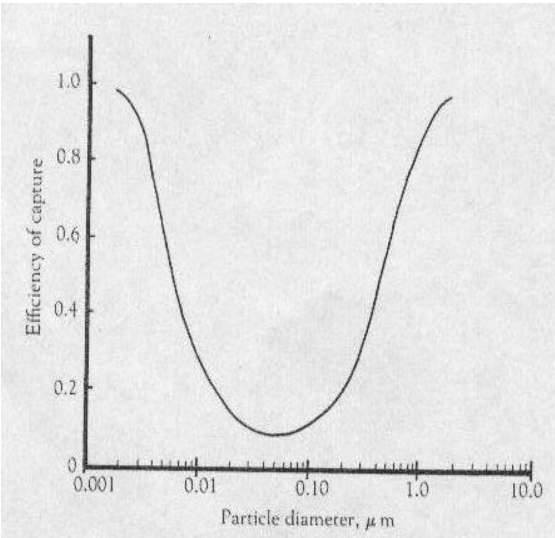
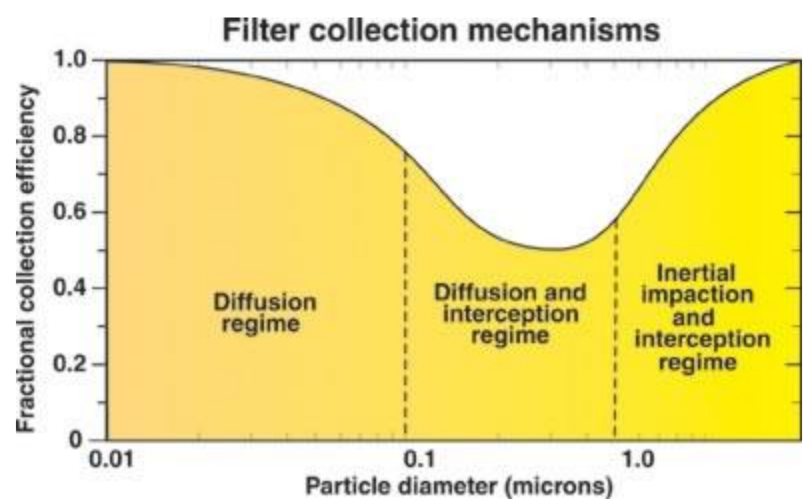


Example: Collection efficiency is greatest for smaller and larger particles and least for particles in a mid range of ~0.05-0.1um

Particle capture profile of a 5 um polycarbonate track etched membrane

The profile will shift based on filter type and pore size but the shape will remain



Comparison Between FMLB and New Teflon Membrane

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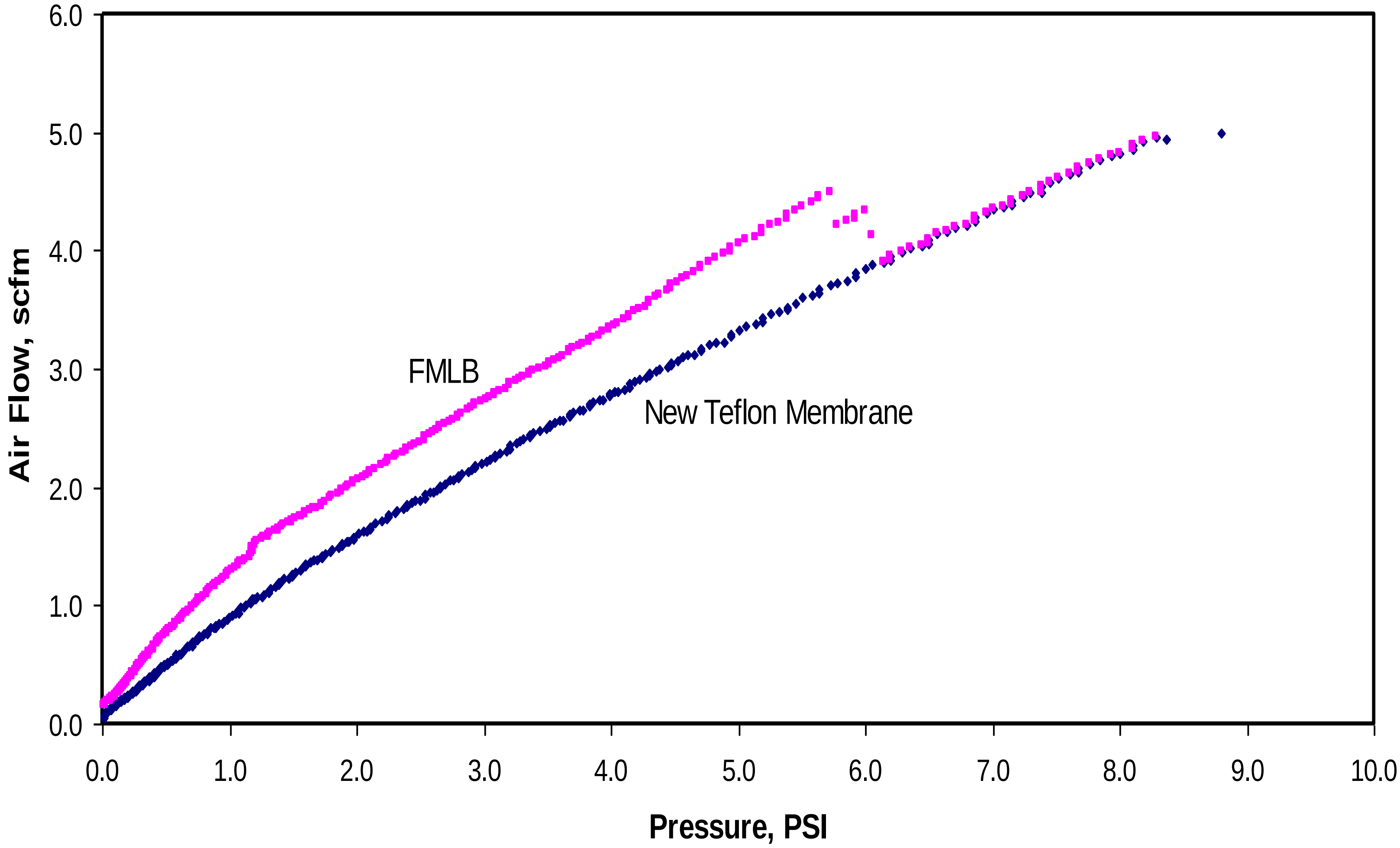
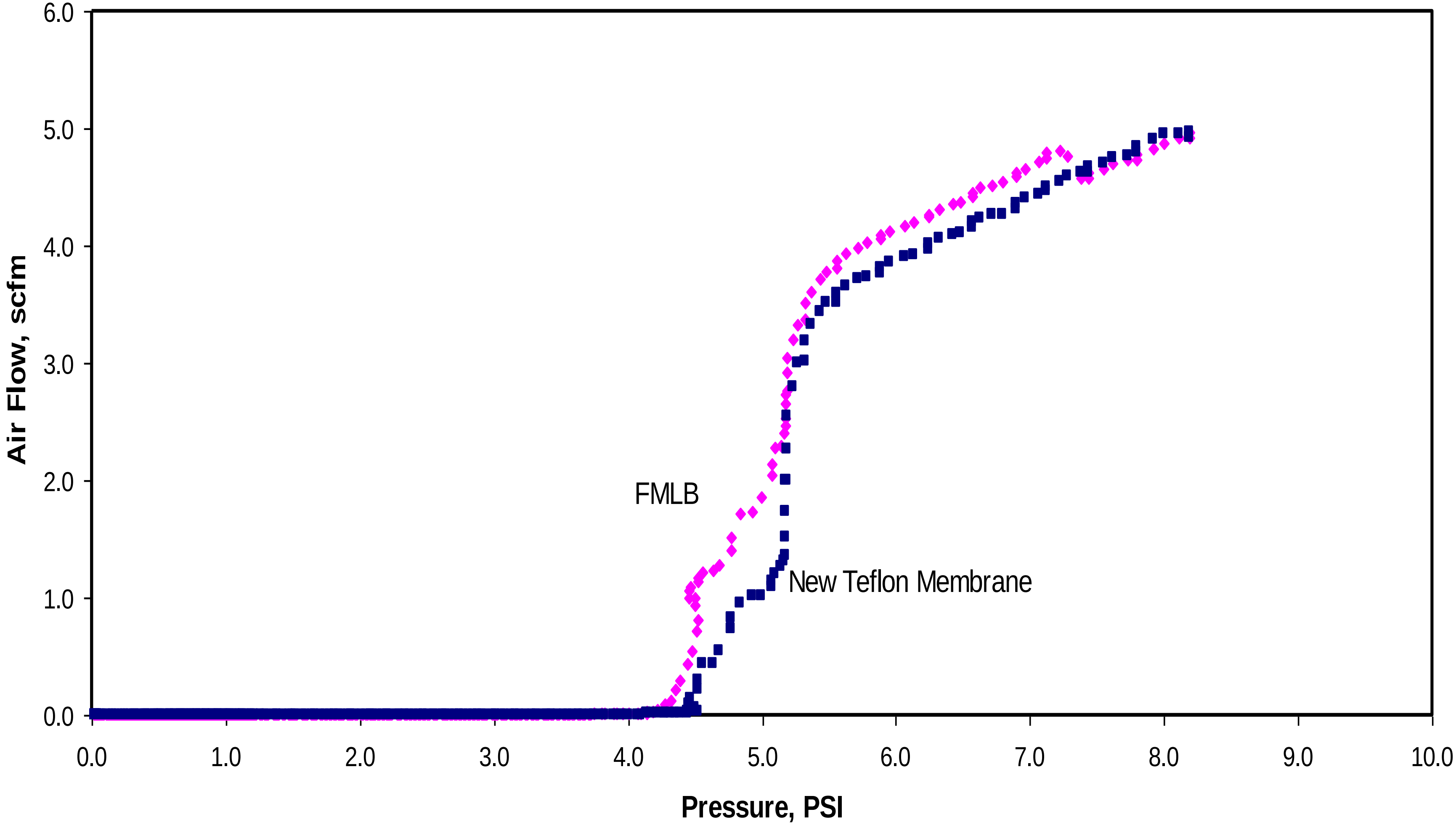
Parameter	FMLB	New Teflon Membrane
Thickness, µm	237.0	280.0
Bubble Point, IPA, PSI	2.0	2.1
Wettability	Hydrophobic	Hydrophobic
Pore Size	5 µm	5 µm
% Porosity	89.5%	90.4%
Air Flow Rate, @ 8PSI	5.5 scfm	5.0 scfm
Water Flux, sec	34.5	48.0

FMLB Vs. New Teflon- Dry



FMLB Vs. New Teflon- Wet



Fluoropore- Dry

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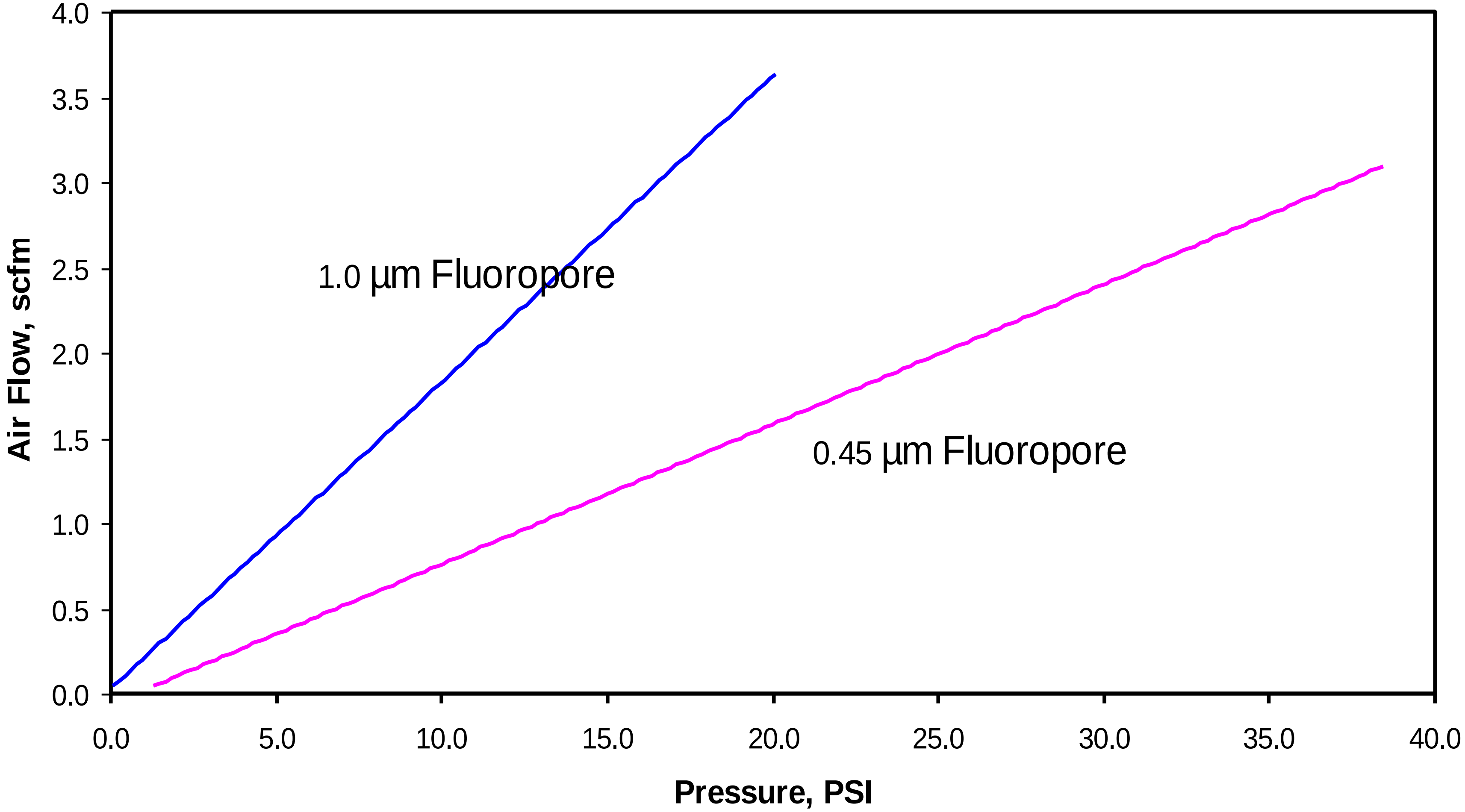
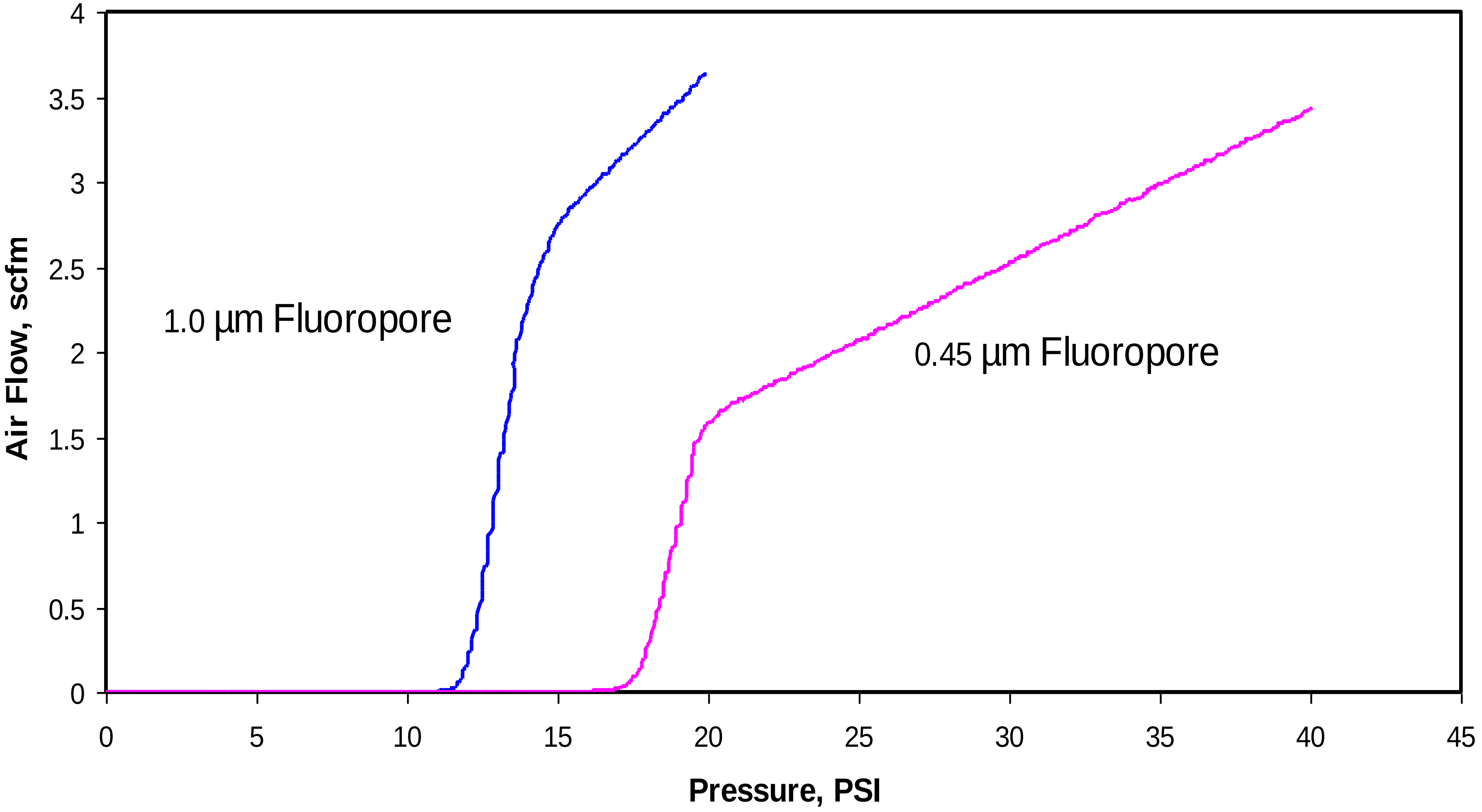


Fluoropore- Wet



Applications of Nano-particles

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- Biochemistry and Mol Bio - Biosensors, delivery systems, imaging, gold nanoparticles, cell transfection
- Chemistry & Chemical Engineering - nanodispersion methods, structure and behavior, materials, synthesis
- Computer Science - lithography, memory, sensors, nanocomposites, electromagnetic properties
- Energy - solar cells, heat treatment, catalysis, fuel cells
- Environmental - atmosphere, sensors, health threats, removal, risk management
- Materials Science – manufacturing and properties
- Medicine - imaging, drug delivery and diffusion, tumor targeting, vaccine, detection
- Pharmacology&Toxicology - nanoencapsulation, drug delivery, microemulsions, inhalation effects

Materials

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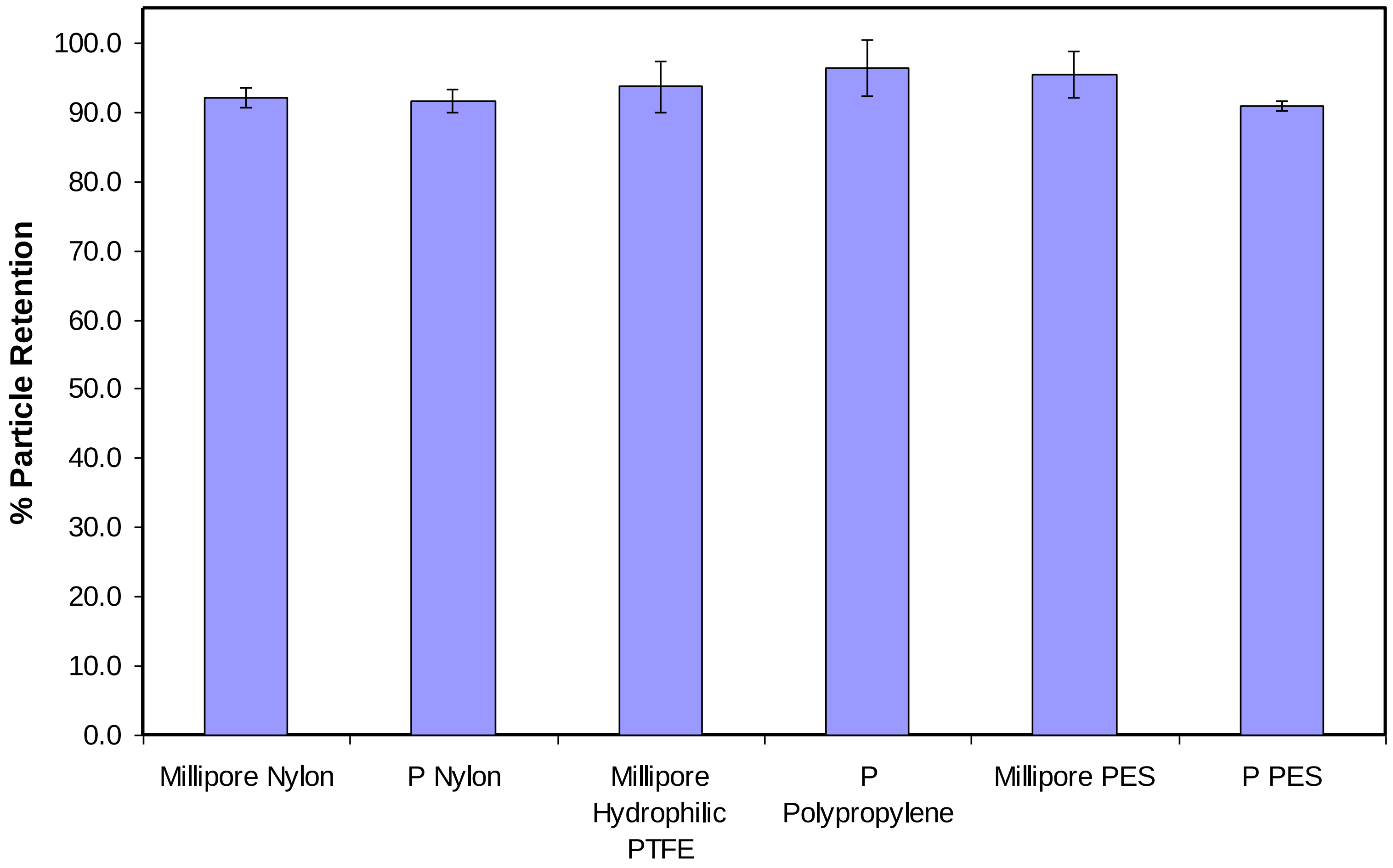
- The cationic polylactic acid (PLA)
- Methoxypolyethyleneglycol-PLA (MePEG-PLA)
- Metals - Au, Zn, Cd, Ag, Fe, Pd, Pt
- Silica-coated gold
- Carbon nanotubes and nanofilaments
- Magnetic particles (superparamagnetic iron oxide)
- Latex

Retention of 0.5 um Latex on 0.45 um



Retention Efficiency of different membranes is different

Retention of 0.3 um particle on 0.2 um membrane

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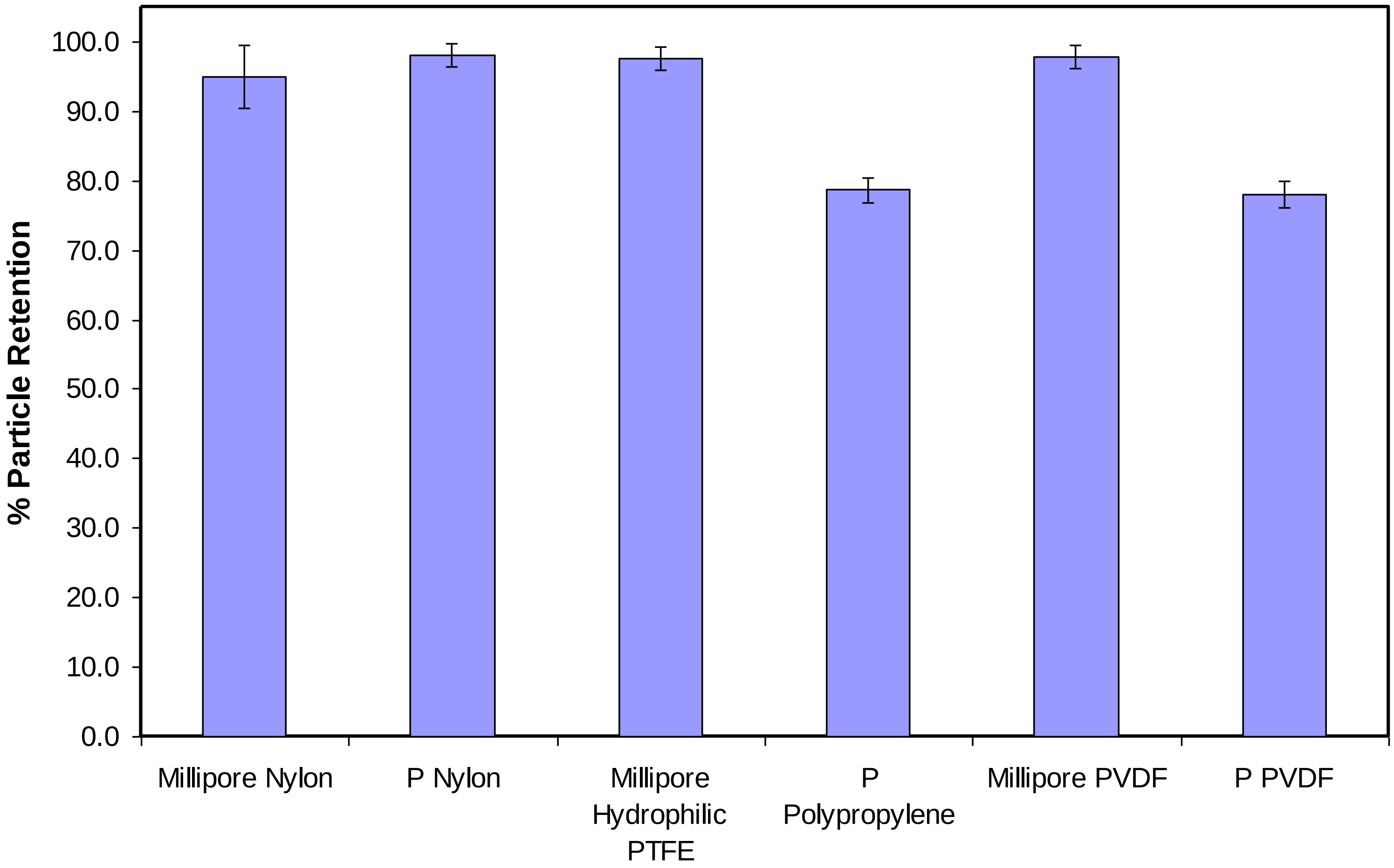
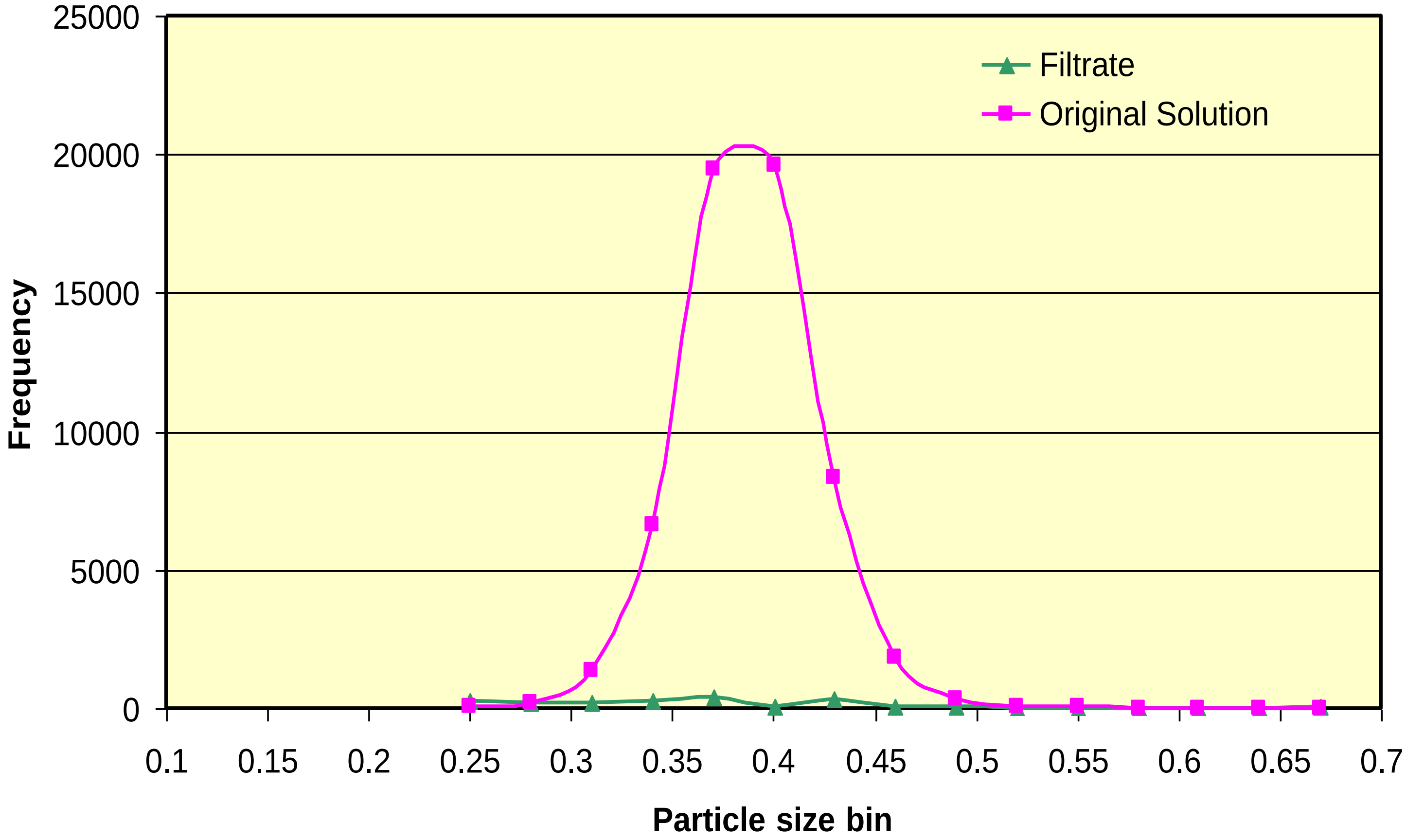


Retention Efficiency of different membranes is different

Effect of Filtration on Particle Size Distribution



Post Filtration particle size distribution clearly shows quantitative retention of particles

Retention of Particles on Nylon Membranes (0.1 um / 0.45 um)

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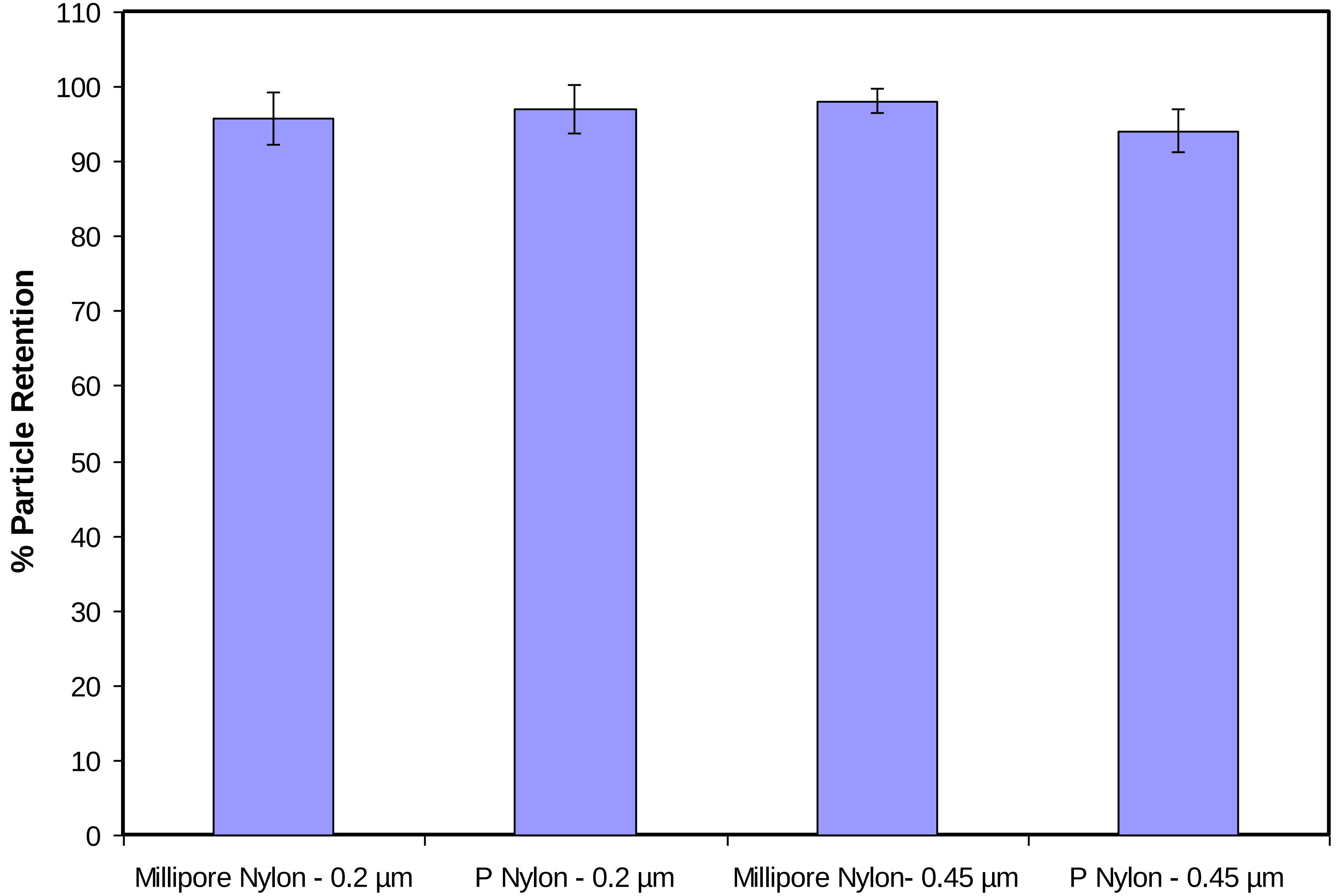
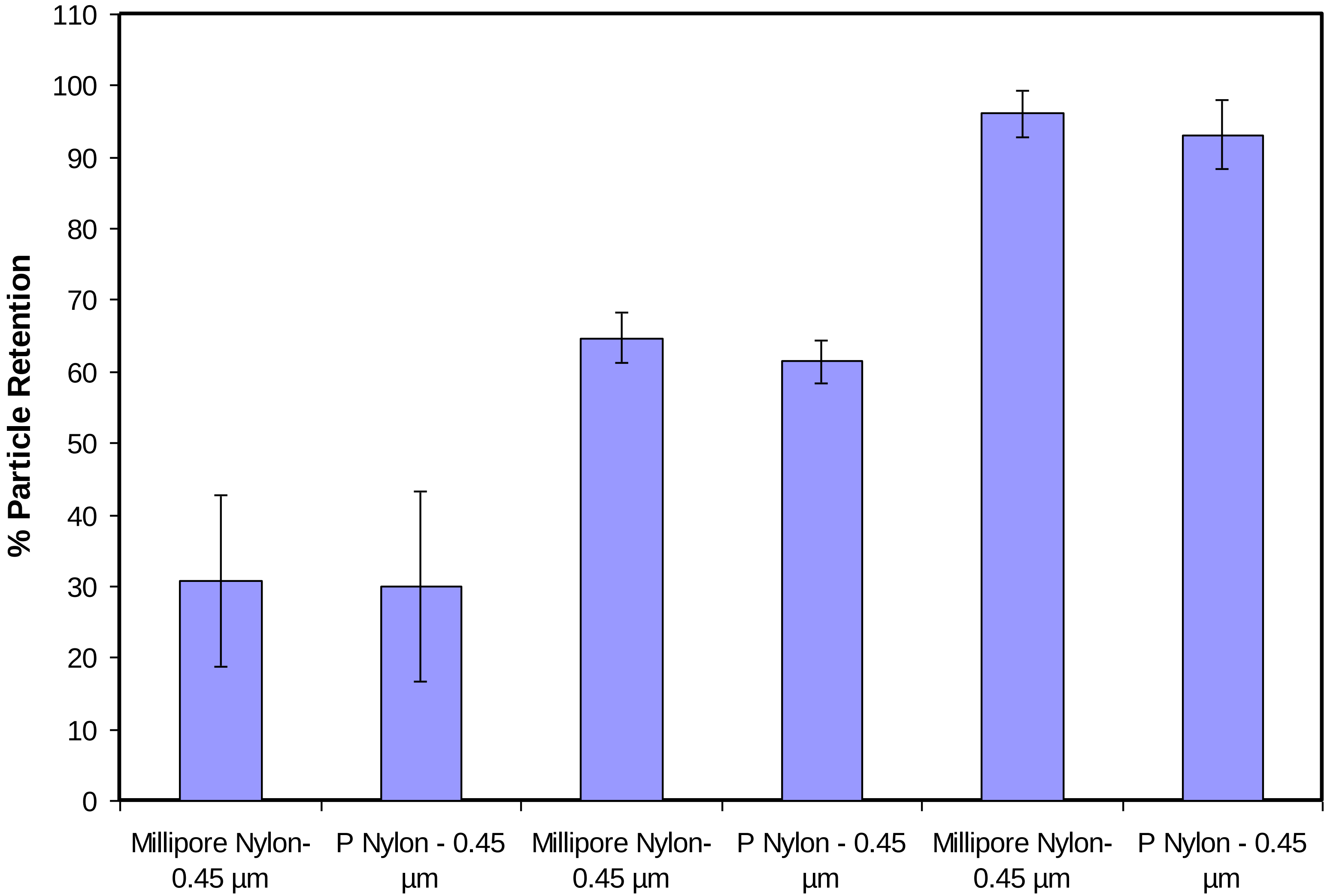


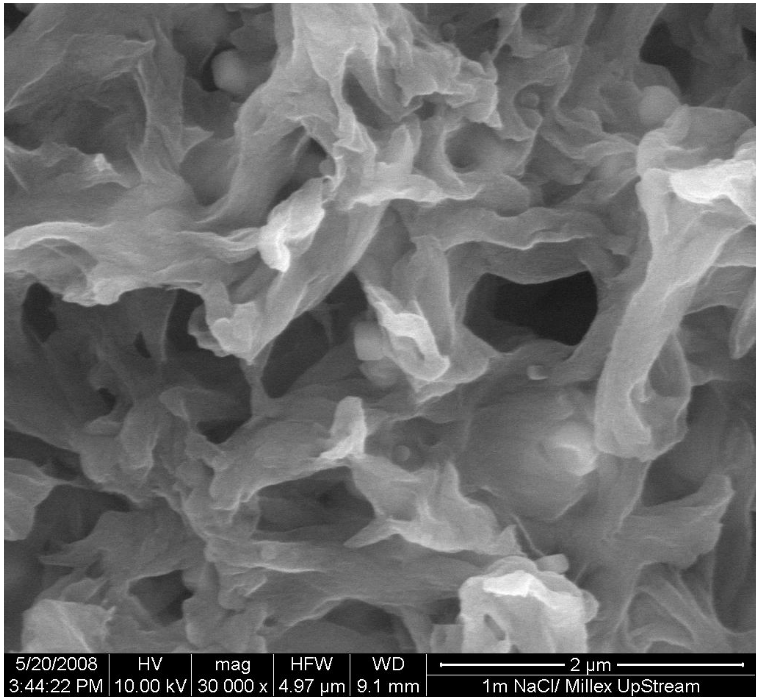
Nylon membranes show higher retention of particles due to electrostatic interactions

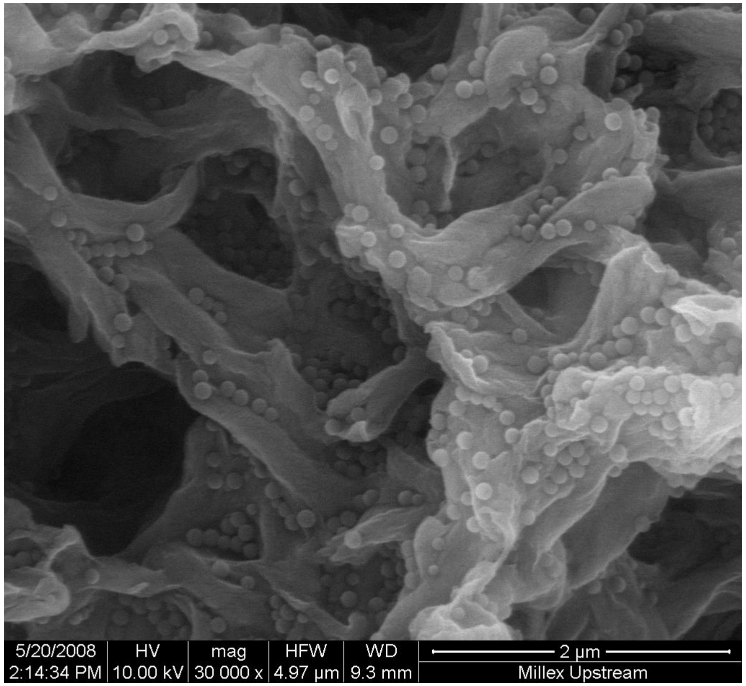
Salt Effect



Addition of salt shows that electrostatic interaction shows a big part in retention of particles

Upstream: 1 N NaCl Vs. No salt





X-Section: 1 N NaCl Vs. No Salt

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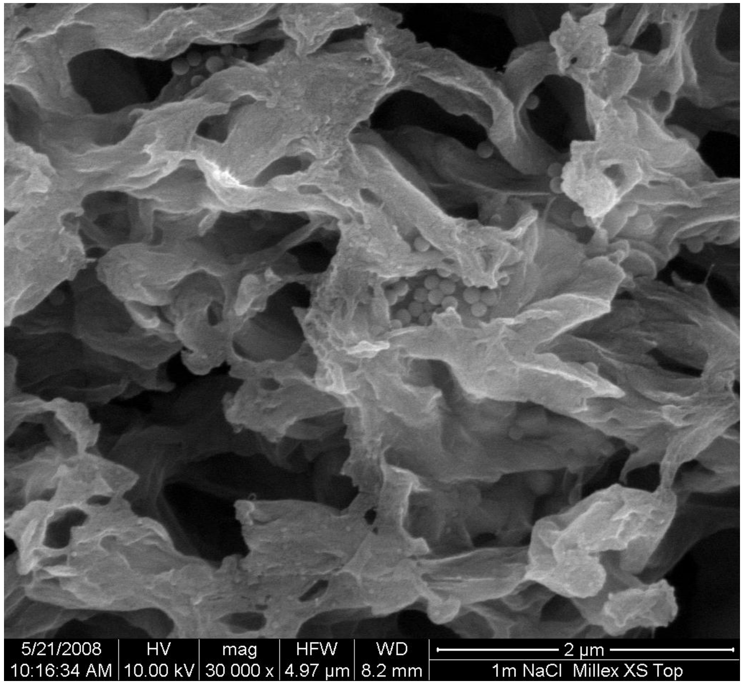

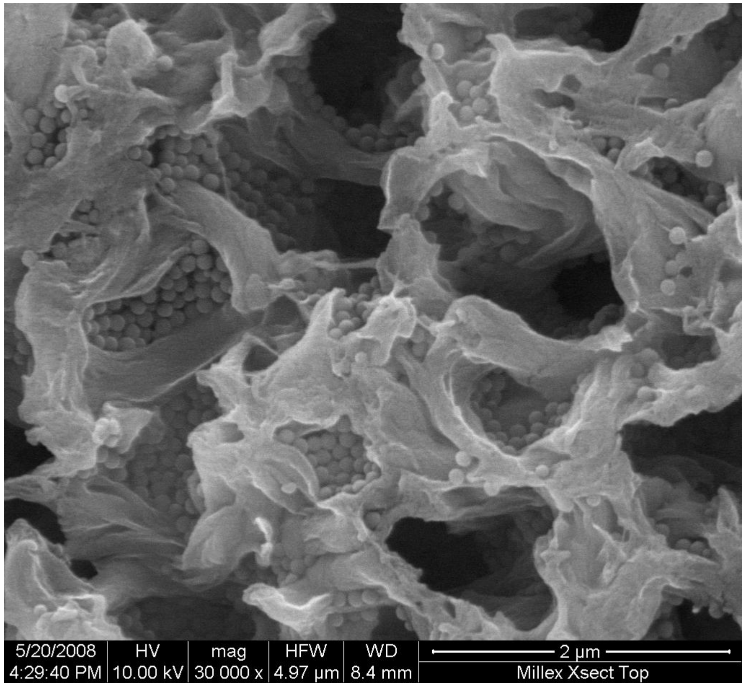

Thank you

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