Lydall Performance Materials

Nanofiber Selection: Designing Filtration Media for High Efficiency Air Filtration Applications

Presented by:

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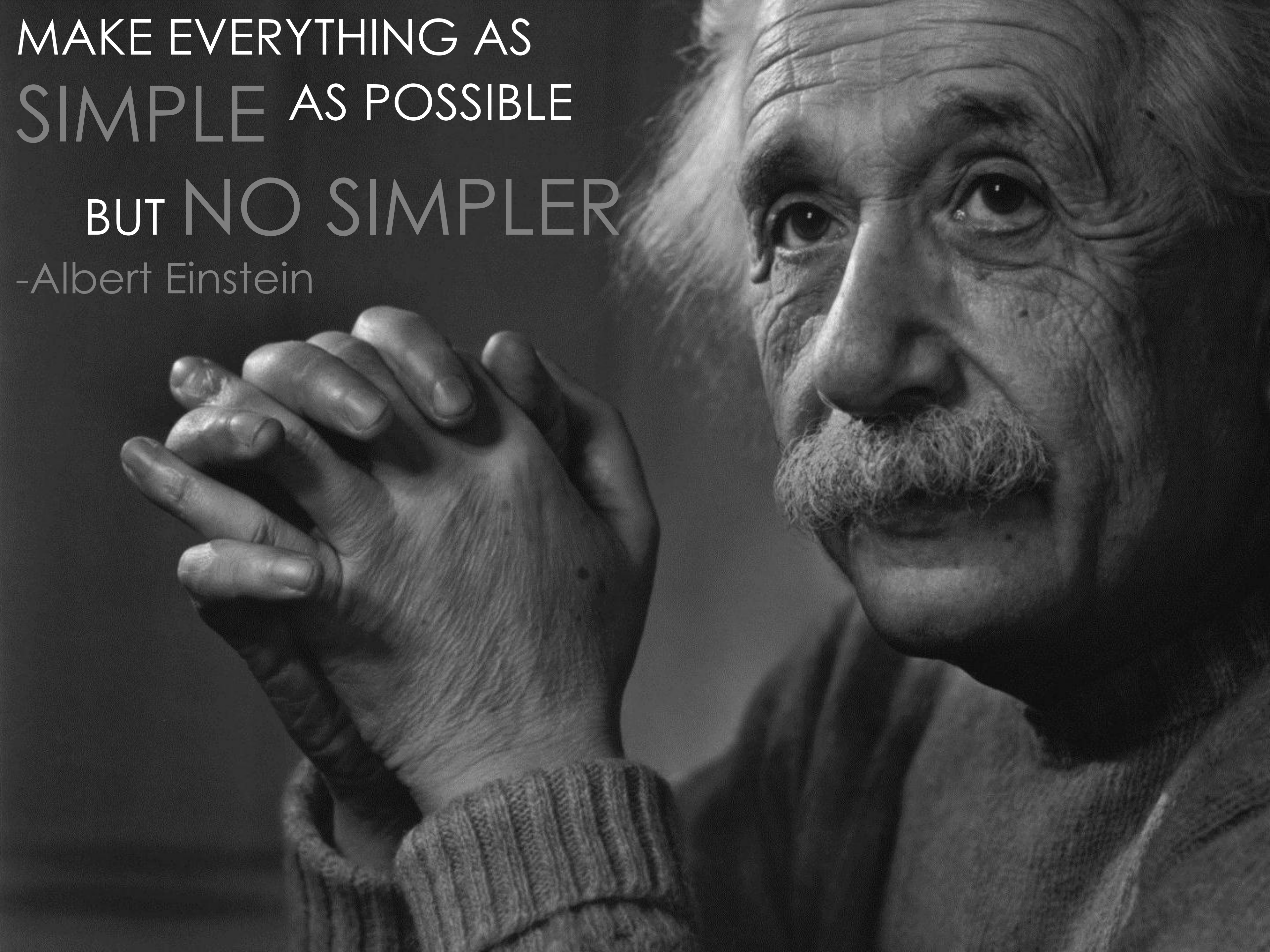
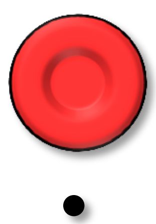
IEST


MAKE EVERYTHING AS
SIMPLE AS POSSIBLE
BUT NO SIMPLER
-Albert Einstein

What is a Nanofiber?

- Nanofibers are typically defined as fibers with diameters less than **100 nanometers (0.1 μm).**
- In the textile industry, this definition is often extended to include fibers as large as **1000 nanometers (1.0 μm)** diameter.
- They can be produced by electrospinning, forcespinning, meltblowing, extrusion and stretching (membranes) and rotary or flame attenuation (glass).

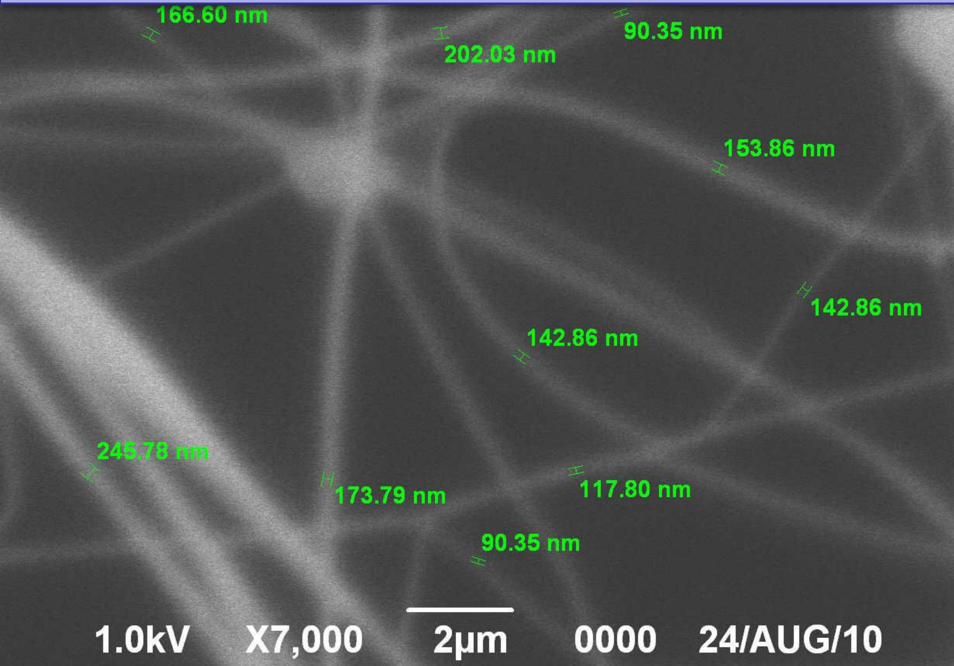
Human Hair 100 um



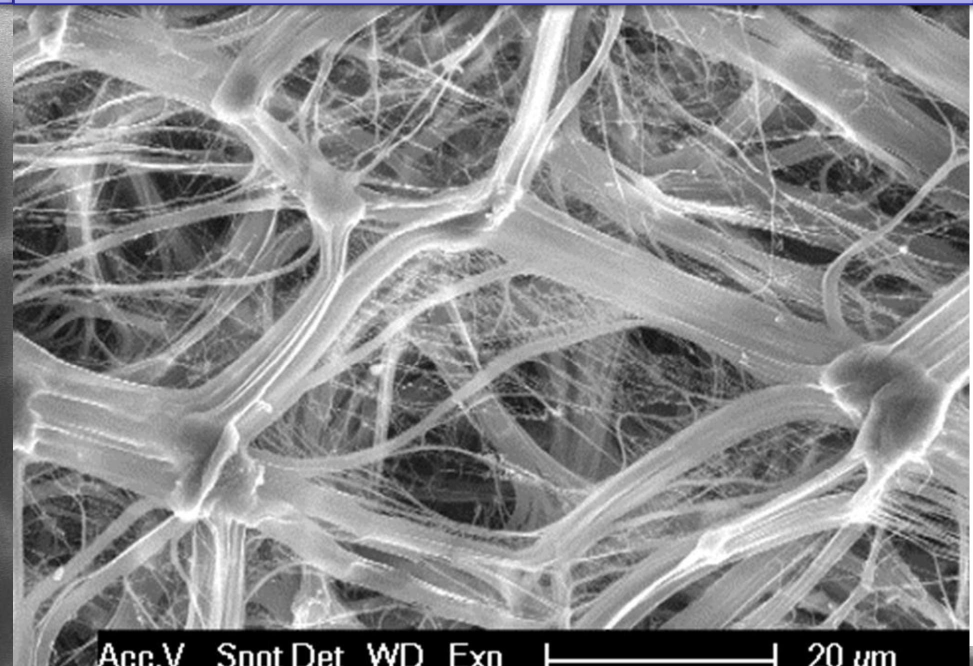
Red Blood Cell 7 um

Nanofiber <1 um

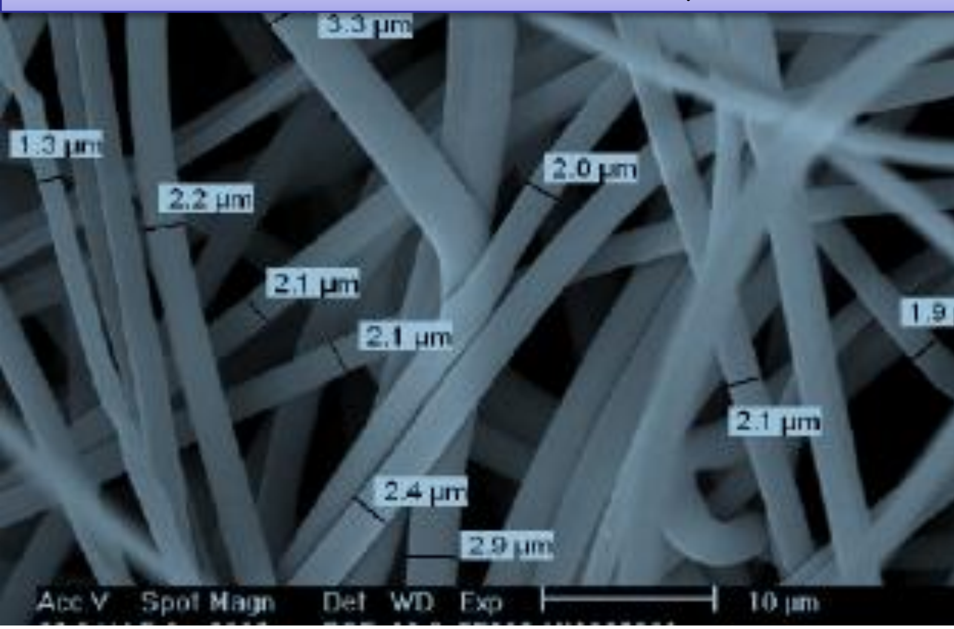
Nanofibers Alone: 0.100 – 0.200 μm



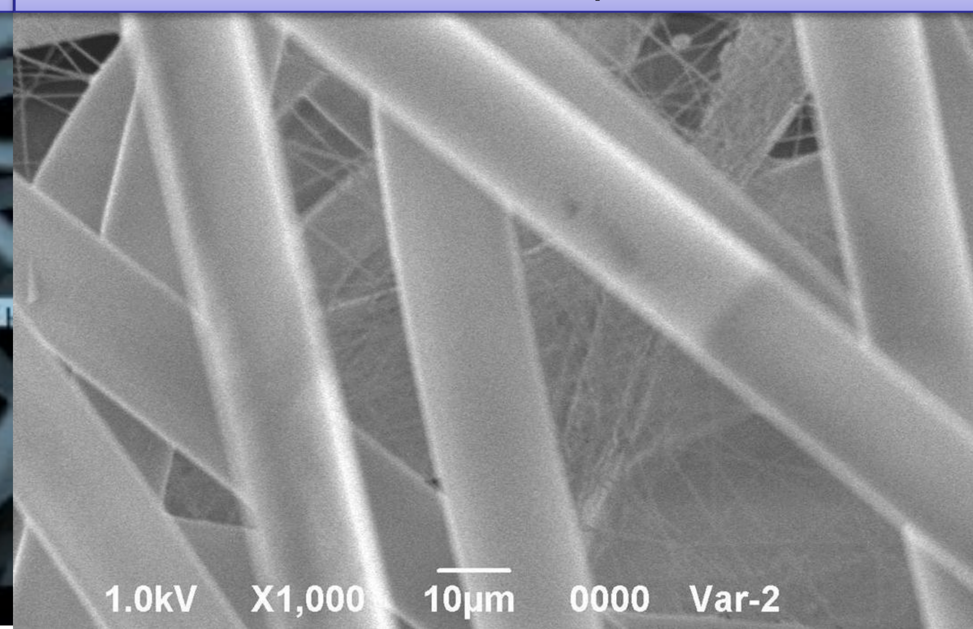
Nanofibers in UHMWPE Membrane



Meltblown Fibers: 2-3 μm



Nanofiber Composite

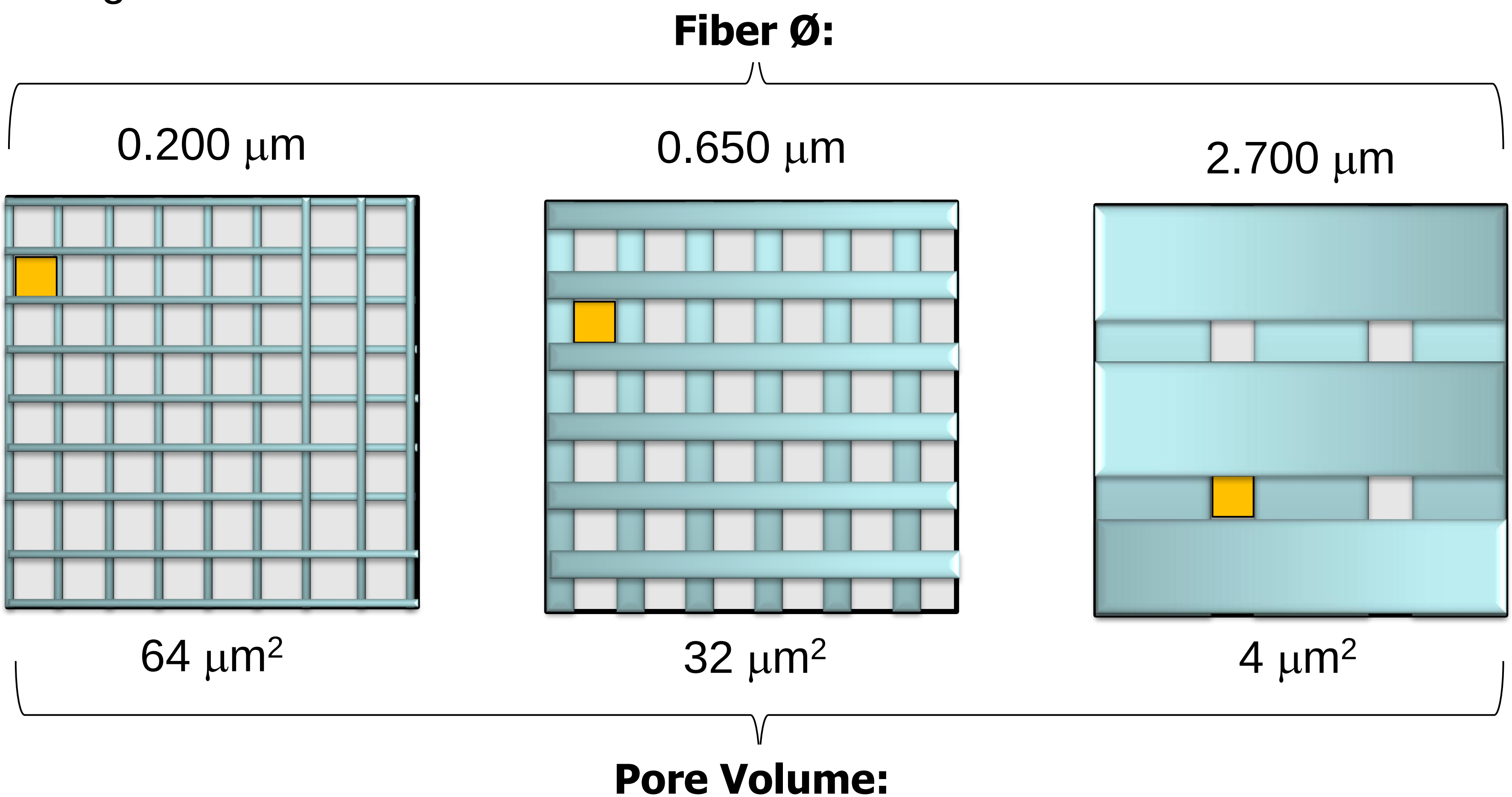


Why Nanofibers?

- High Pore Volume
- Small Pore Size
- High Surface Area

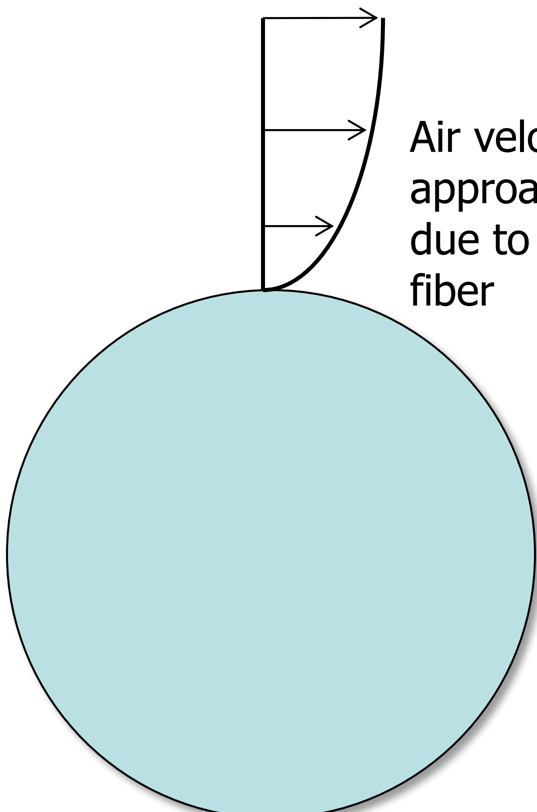
Filter Area: 100 μm^2

Pore Size: 1 μm^2



Nanofibers: Non-linear effect on ΔP

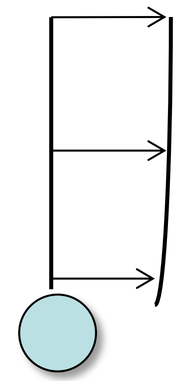
Air velocity



Air velocity approaches zero due to drag on fiber

Fiber Cross-Section
1.5 microns

Air velocity

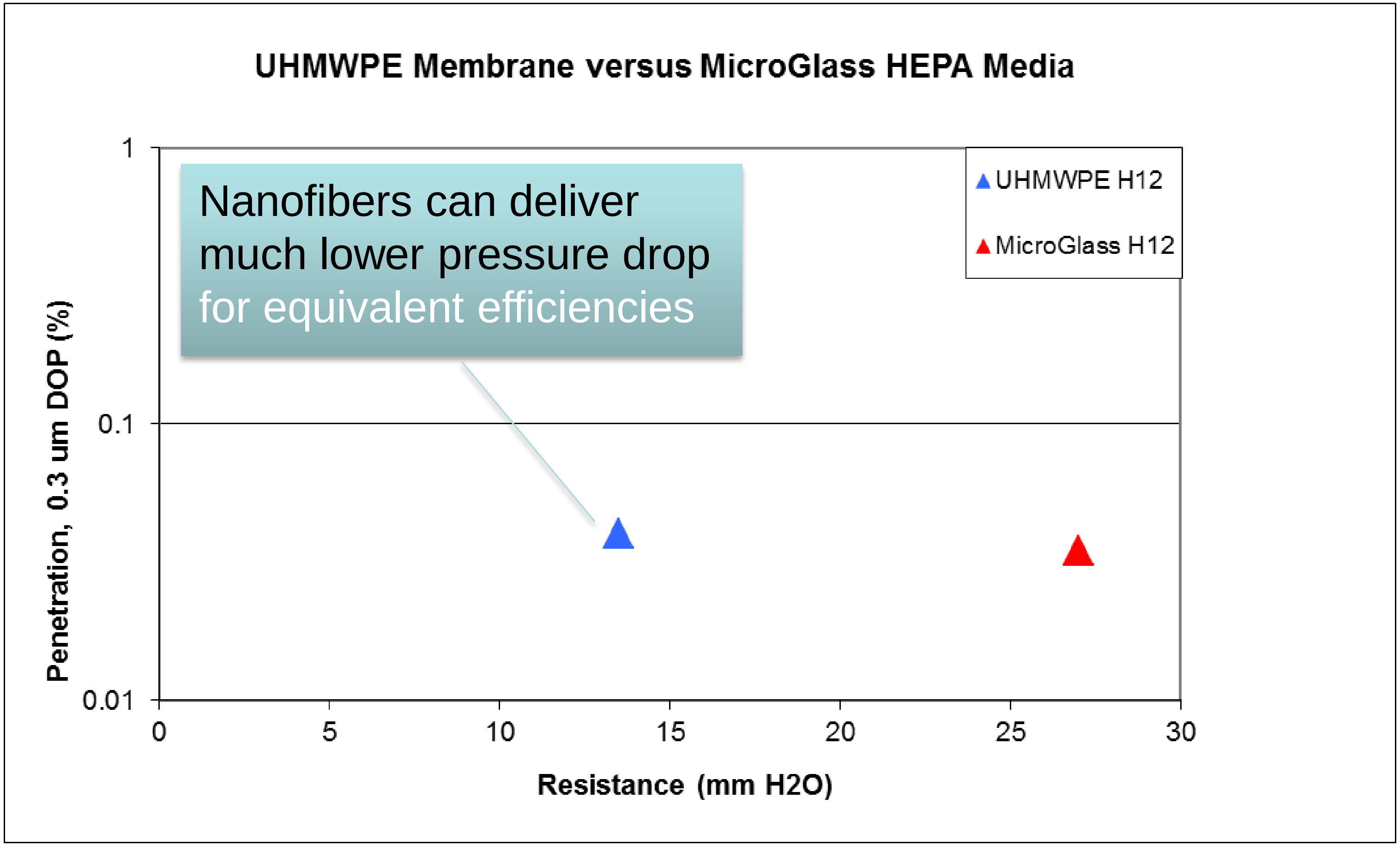


Air velocity nearly unaffected by nanofiber because of “slip flow”

Less surface area presented to the air stream results in less drag.

Fiber Cross-Section
0.2 microns

Nanofibers: Energy Reduction Possibilities



* The efficiency ratings for this test used 0.3 micron DOP particles on a TSI Model 8160 automated test stand on flat sheet media samples at 5.33 cm/second.

Filtration: What are we trying to do?

Cleanspace
High Efficiency, Low Dust Loading

Gas Turbine Intake
High Efficiency, Medium Dust Loading

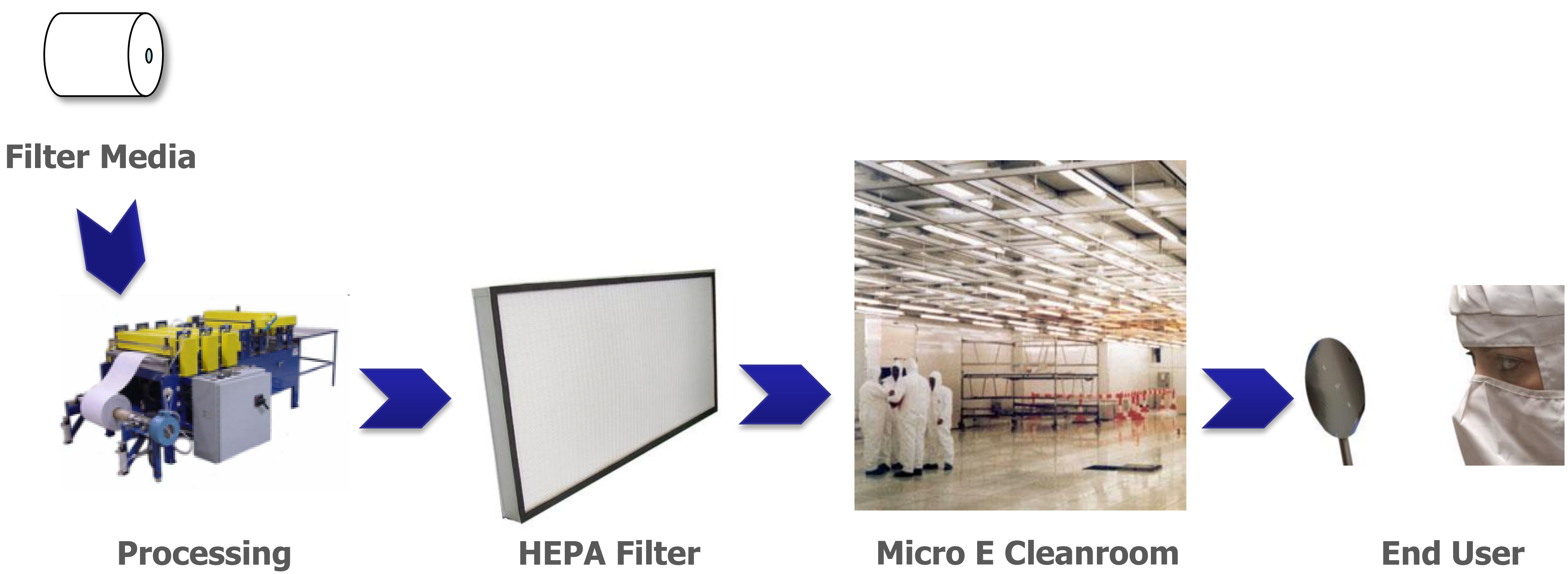
Dust Collection
Moderate Efficiency, High Dust Loading

Respirator
Moderate Efficiency, Low Resistance

Your application defines your performance requirements – sort of…

What do filtration fibers withstand?

- What do filters withstand:
  - QC Testing, Packaging, Shipping, Installation, Dust loading, Pressure Impulses, Moisture, Temperature, Hydrocarbons, VOCs
- What does filter media withstand:
  - Winding, Unwinding, Pleating, Heat, Hot Melt Glues, Potting Compounds



Media Strength and Durability versus Resistance

Desired Outcomes

- Pleatability – Pleat Geometry
- Pleat Tip Durability
- Fiber Tie Down
- Low Resistance
- Environmental Requirements

Media Manufacturer Tool Kit

- Fiber Diameter, Length & Material
- Binder Systems
- Fiber Entanglement
- Thermal Bonds
- Lamination

How will we measure?

Flat Sheet Testing

TSI 3160

PALAS MERV Tester

VDI 3926

Drop Shape Analyzer

Filter Lab Testing

Filter Test Duct

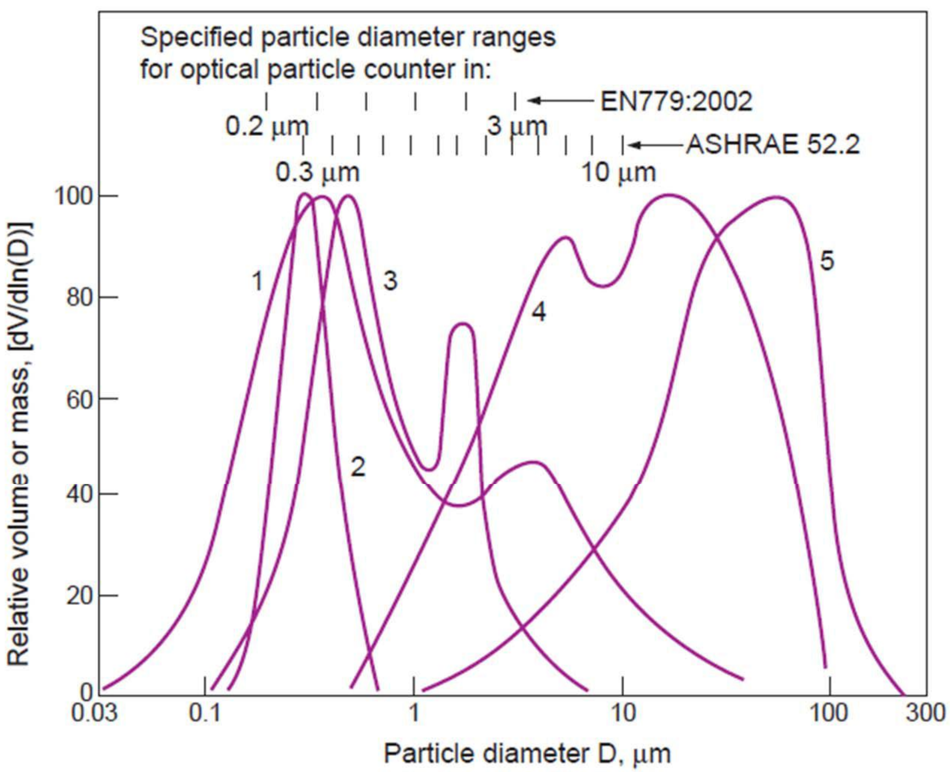
Filter Field Testing

Field Scan

Where does our friend Heisenberg fit in?

Test Aerosols versus "Reality"

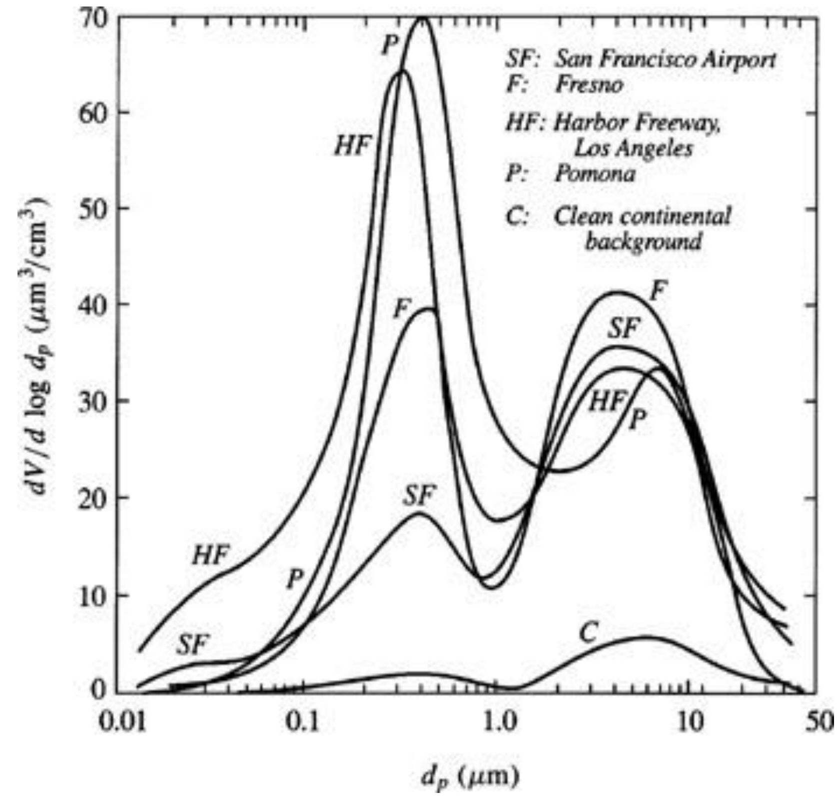
Test Aerosols Aerosol Size Distribution



1) Vienna ambient aerosol [Berner, Atmos. Envir. 38:p3959]
2) MIL-STD-282 DOP Aerosol
3) ASHRAE 52.2 KCl aerosol
4) ISO-12103-1-A2 fine Arizona road dust
5) ISO-12103-1-A4 coarse Arizona road dust

Source: Tronville P., Rivers R.D., "International standards: filters for vehicular applications" in Filtration & Separation, v. 42, n. 9, p. 24-27, November 2005

Atmospheric Aerosol Size Distribution



Source: Smoke, Dust, and Haze: Fundamentals of Aerosol Dynamics, Second Edition

Velocity.

"Chicken wire is a chicken filter.

Up to a certain velocity."

[Click here for video]

Nanofiber Materials

Standalone Nanofibers

Glass Microfiber

down to 0.200 microns

Synthetics

Nylon, PP, PBT, PVA, Polystyrene

down to 0.100 microns

Inorganic (Ceramics)

TiO_2, SiO_2, Al_2O_3, others

Captive Nanofibers

Membranes

ePTFE

UHMWPE

Material Characteristics

Fiber Type	Maximum Operating Temperatures Degrees F (C)		Chemical Resistance						
	Dry Heat	Moist Heat	Strong Acids	Weak Acids	Strong Alkalis	Weak Alkalis	Solvents	Oxidizing Agents	Hydro-lysis
UHMWPE	176 (80)		****	****	****	****	****	****	****
Polypropylene	200 (93)	200 (93)	****	****	****	****	****	***	****
Polyester	275 (135)	200 (93)	***	***	*	**	***	****	*
Nylon (Polyamide)	250 (121)	225 (107)	*	***	***	***	***	***	**
PTFE	500 (260)	500 (260)	****	****	****	****	****	****	****
Glass	500 (260)	500 (260)							

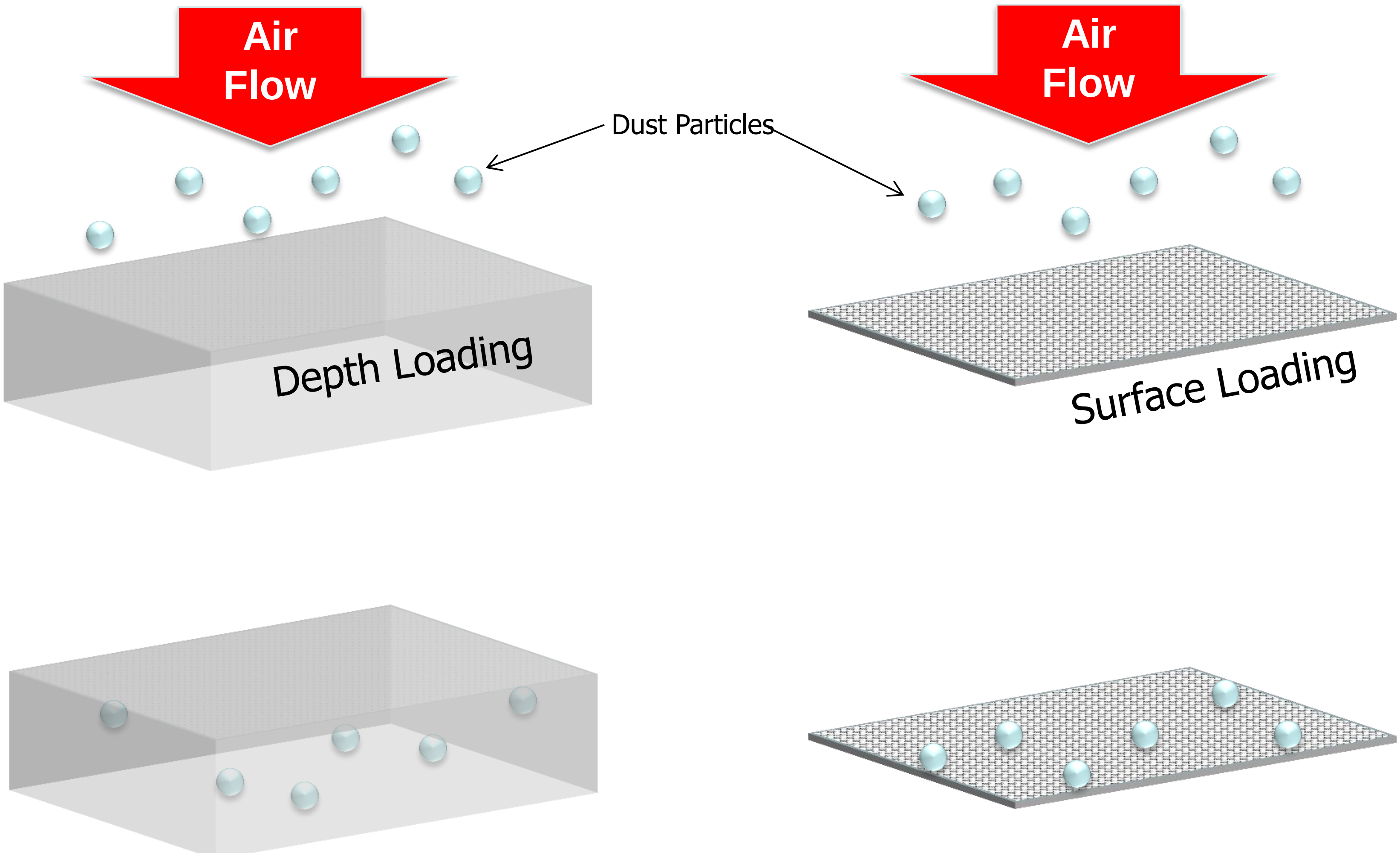
Hydrophobic versus Hydrophilic
Oleophobic versus Oleophilic

Fiber Tie-Down

Nanofibers must be tied down to be effective, and for long term filter performance.

- Thermal Bonding
- Binder Systems
- Fiber Entanglement
- Lamination
- Captive

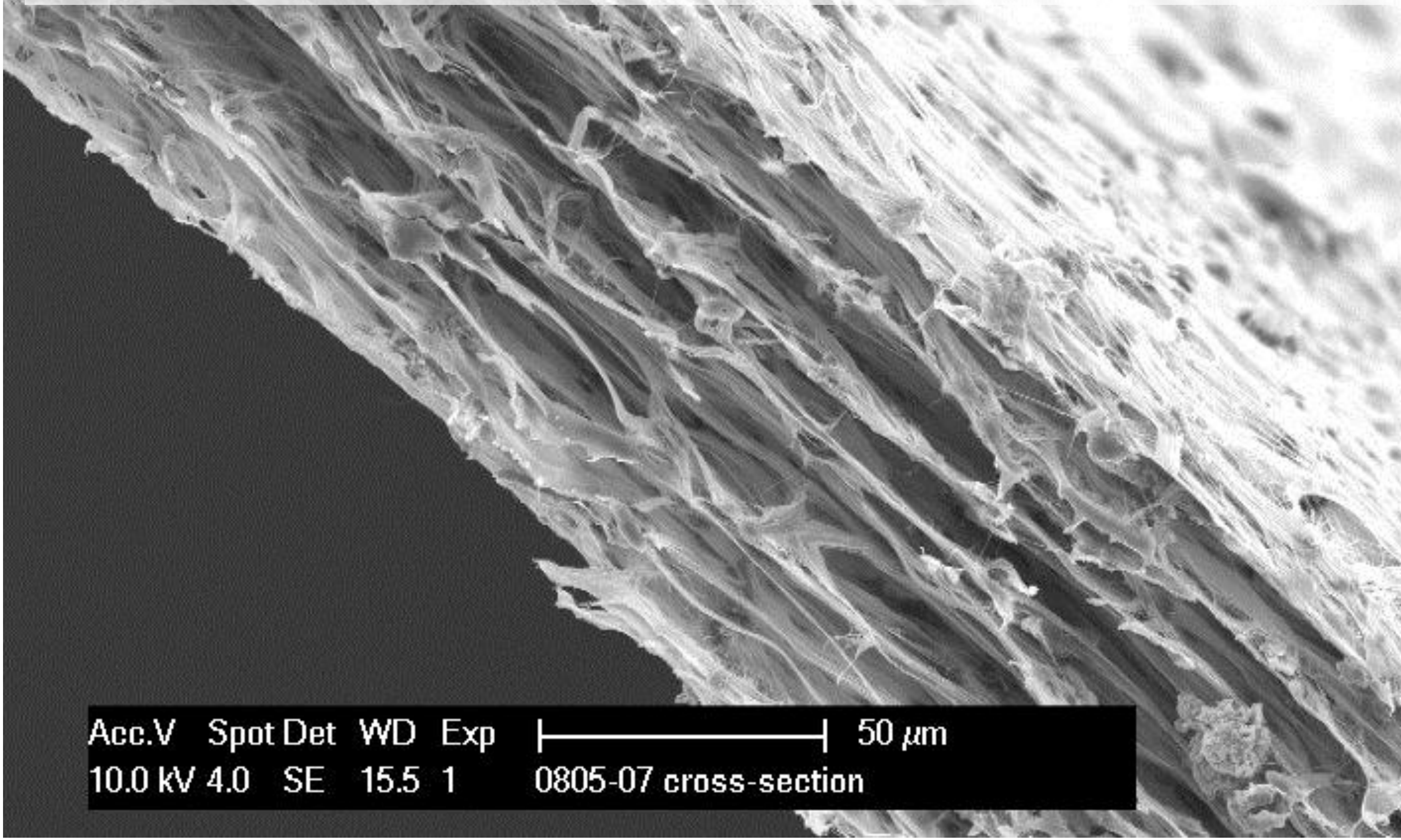
Depth Loading versus Surface Loading



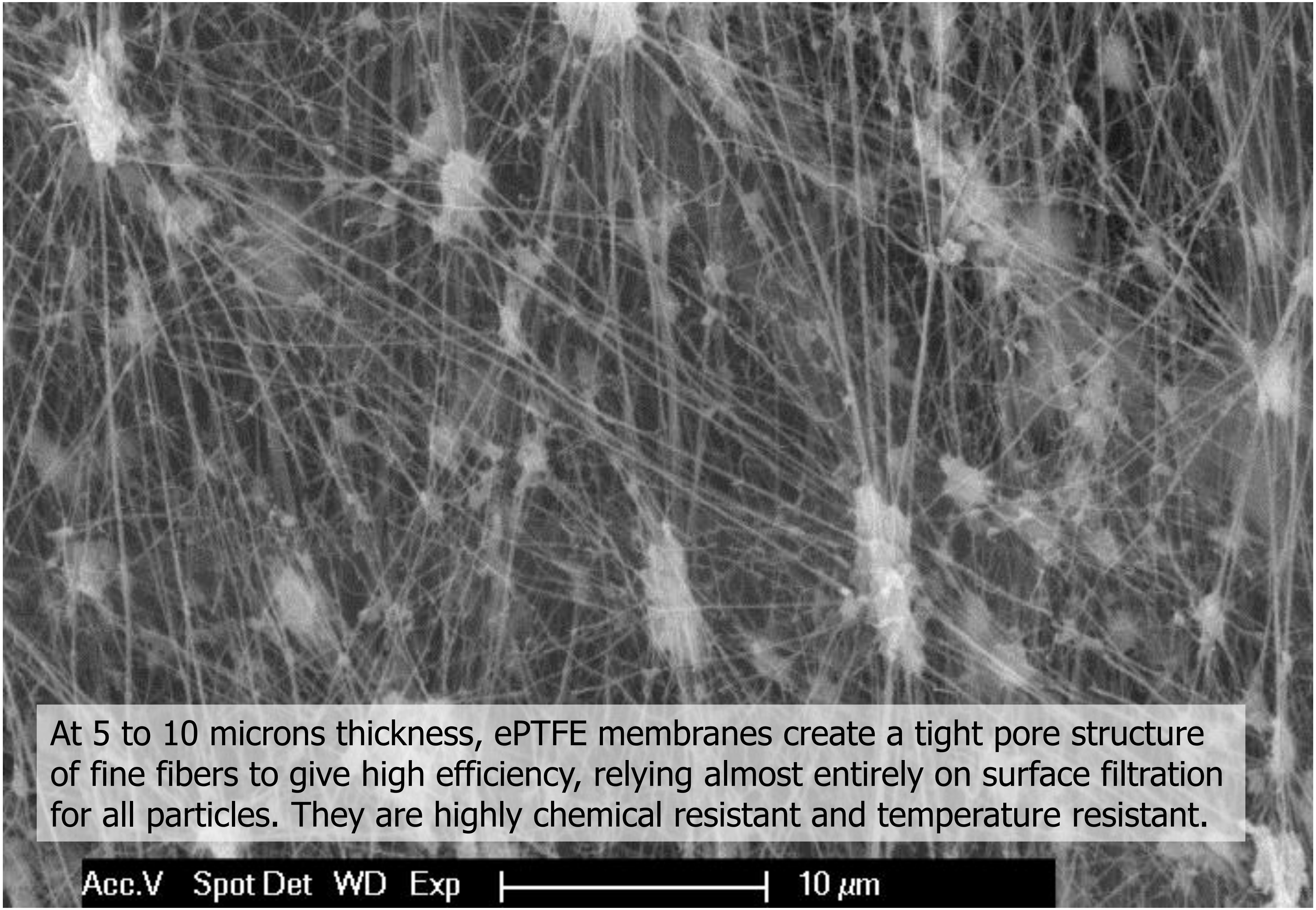
Depth loading media capture particles within their structure, allowing more air to pass , and longer filter life.

Surface Loading media capture particles only on the surface, blinding off against more air flow.

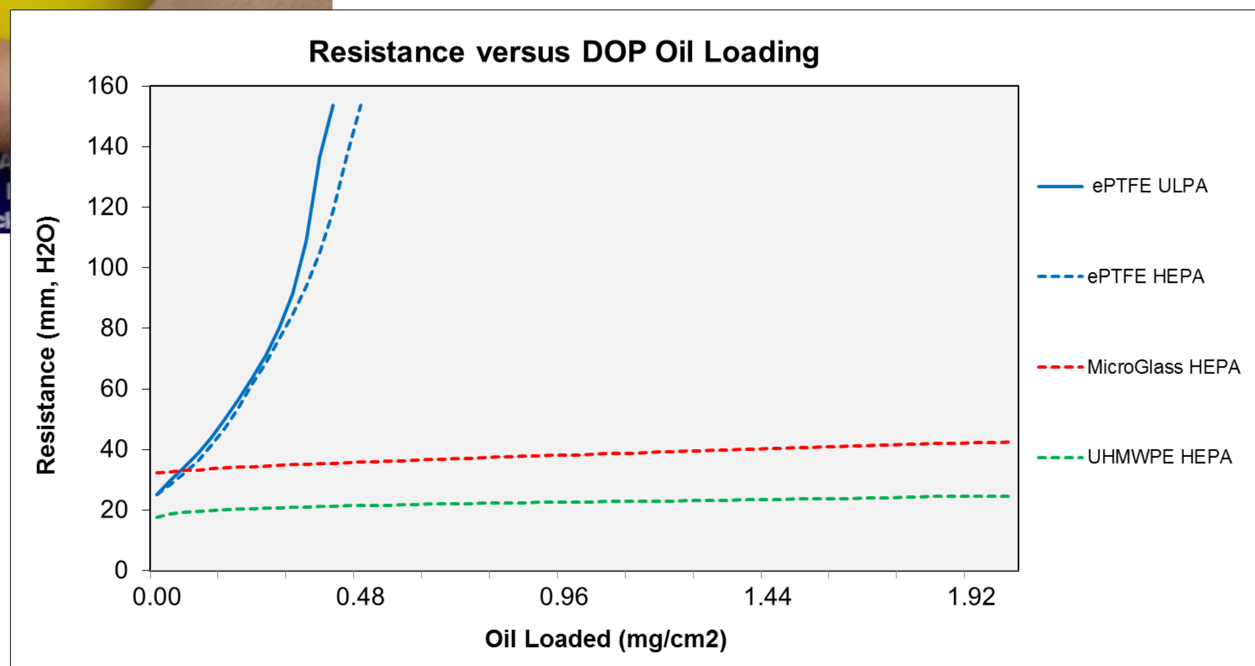
At 100 to 150 microns thick, UHMWPE membranes are composed of continuous structural fibers and integral nanofibers, with a very large void volume and small pore size. This gives high efficiency, very low pressure drop, and the ability to hold small oil particles within its structure.



ePTFE membranes are a thin layer of fine fibers

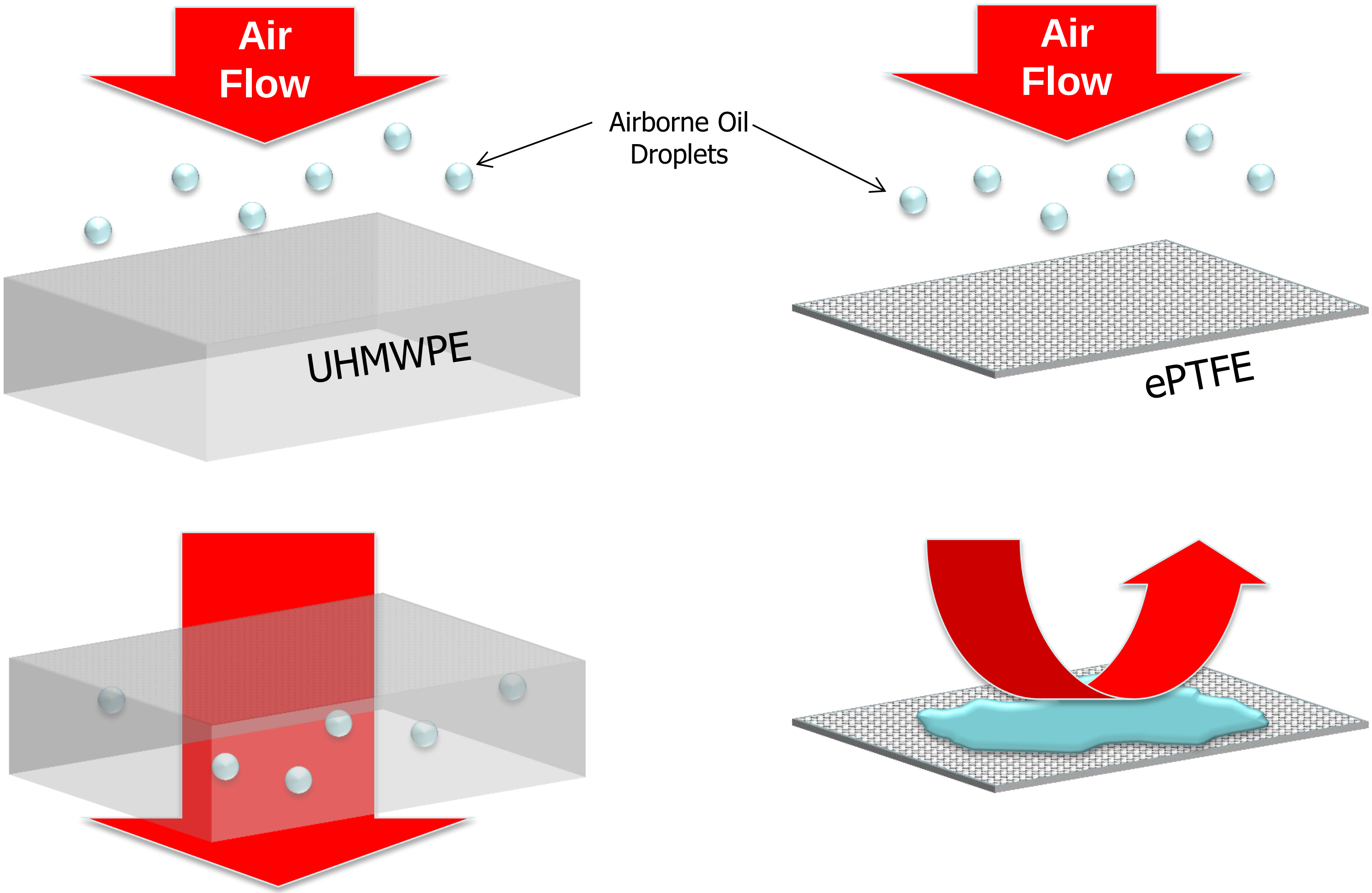


Would you do this in your application?



1.92 mg/cm2 is equivalent to loading a standard 24″ x 24″ V-bank filter with 12 ounces of oil.

UHMWPE handles oil loading differently than ePTFE



Thick, **oleophilic** UHMWPE membranes capture oil within their structure, allowing more air to pass , and longer filter life.

Thin, **oleophobic** ePTFE membranes capture oil only on the surface, blinding off against more air flow, causing very high pressure drop.

Mechanical versus Electrostatic Filtration

Electrostatics:

- Particles of all sizes are affected
- Particles "precipitate" out of the gas stream line
- Directly related to number and strength of "charges"
- *Electrostatic efficiency can reduce over time due to multiple factors*

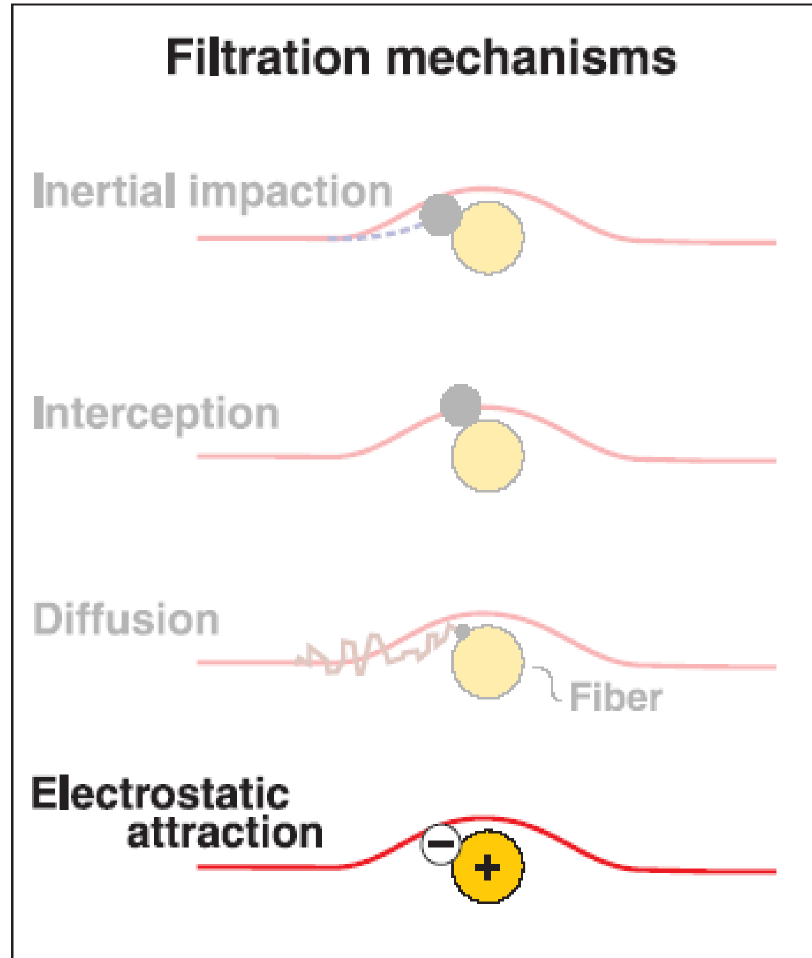


Figure 3. Four primary filter collection mechanisms.

Illustration from NIOSH Booklet *"Filtration and Air Cleaning Systems to Protect Building Environments"* April 2003

Summary

- Nanofibers have distinct advantages in high efficiency filtration
- Your application will dictate requirements placed on the fibers, and fiber selection
- Current test methods may not accurately reflect performance in your application
- All nanofibers are not created equal for your application

Questions?

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Thank You!

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