High Loading Filter Media using Novel Electrospinning Method

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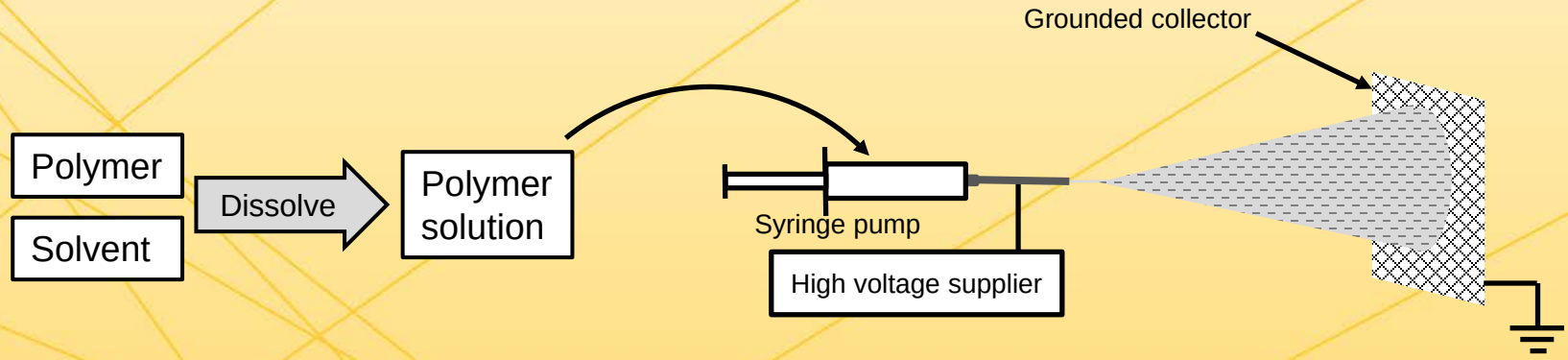
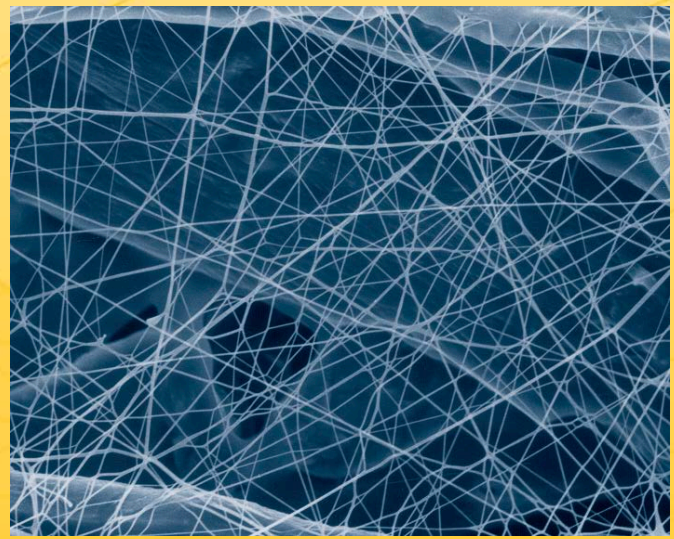
Background

- Electrospinning has been a well-known simple method to fabricate nanofiber.
- Nanofiber filters exhibit high filtration efficiency and relatively low pressure drop across the filters, however low particle loading capacity is one of the main concerns due to its surface loading mechanism.
- This project is an initiative work to develop high loading nanofiber filter media using electrospinning method.

Electrospinning





SEM image from Donaldson.com

Transparent Filter (Stanford University)

Transparent filter (Stanford University)

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Transparent air filter for high-efficiency $PM_{2.5}$ capture

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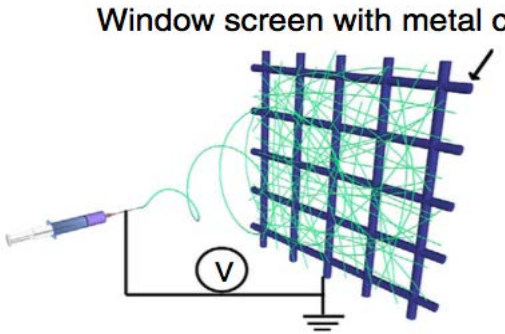
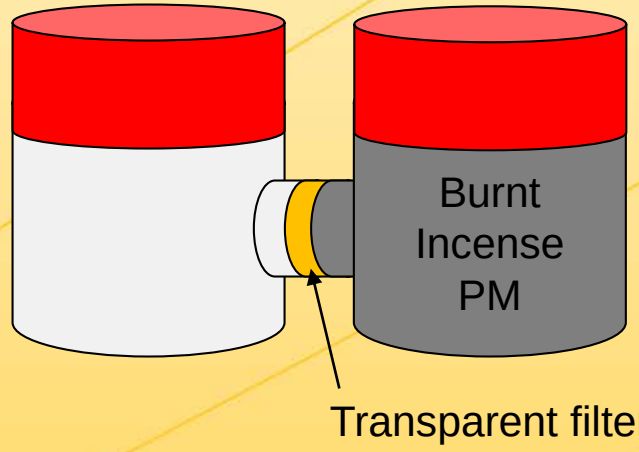
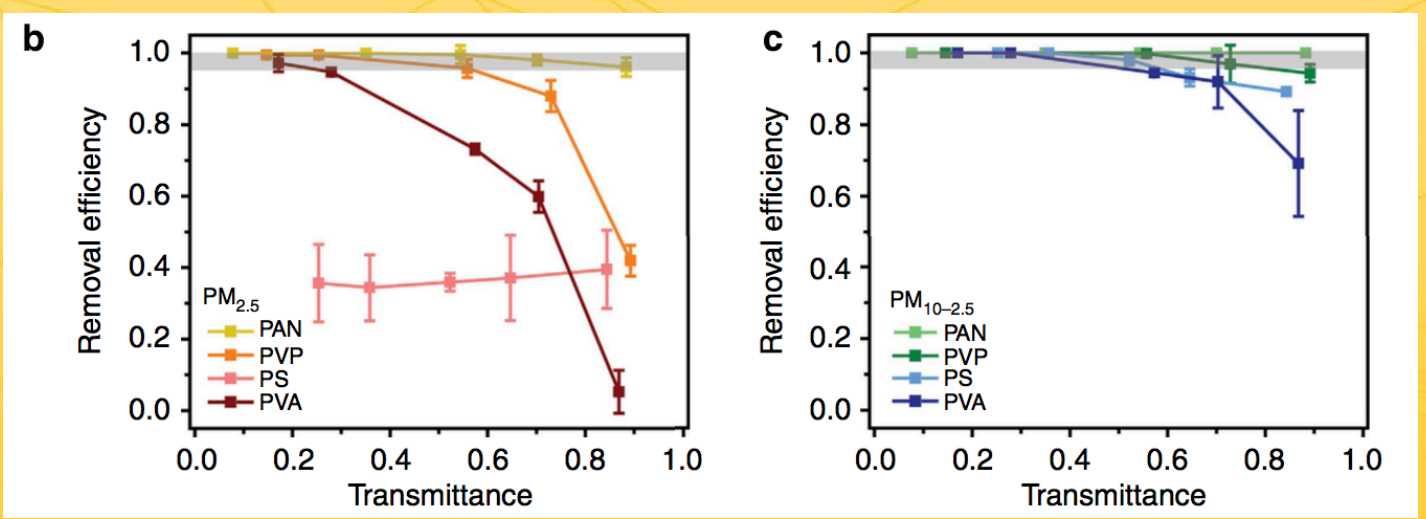


http://news.stanford.edu/2015/02/18/filter-air-pollution-021815/

PM removal efficiency result (Stanford U.)


PM removal efficiency demonstration setup





Pressure drop result (Stanford University)

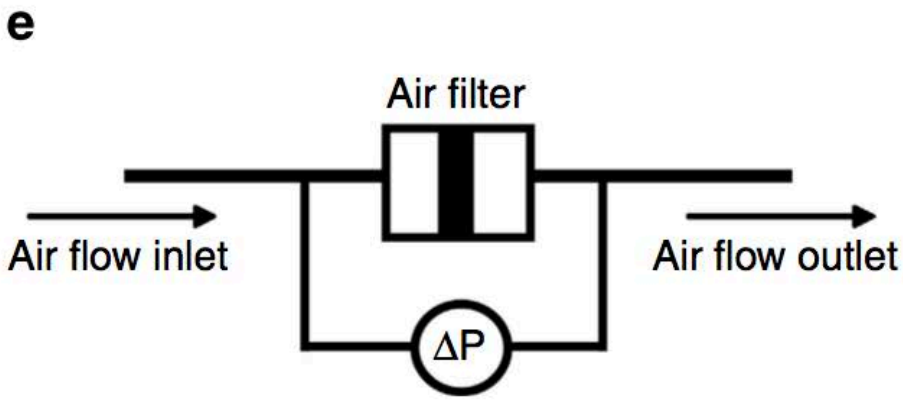


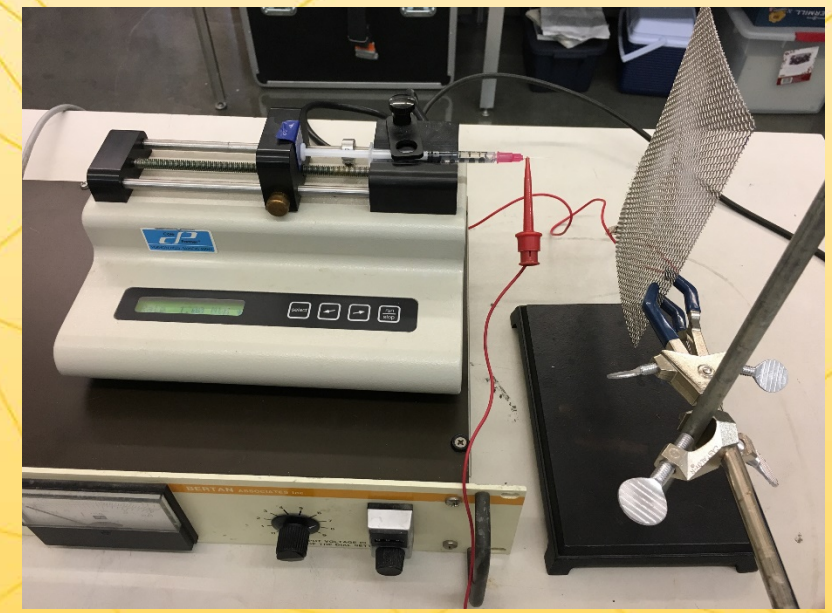
Table 1 | Performance summary of transparent air filters compared with commercial air filters.

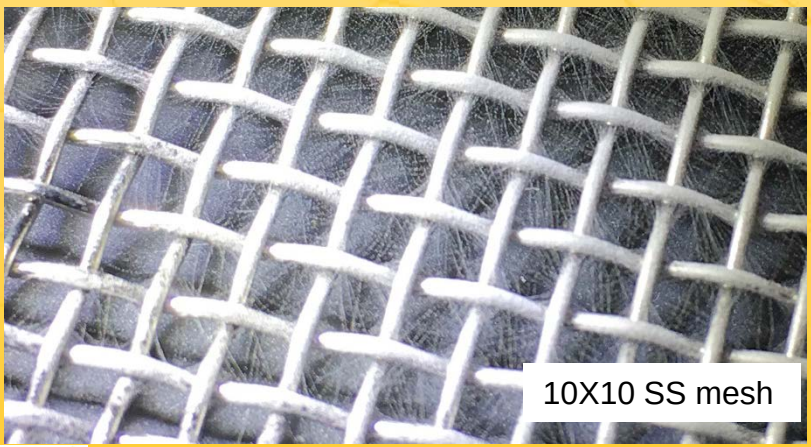
Sample	*T* (%)	*E* (%)	Δ*P* (Pa)	QF (Pa^{-1})
PAN-85	85	96.12	133	0.024
PAN-75	75	98.11	206	0.019
Commercial-1	15	16.93	299	0.00062
Commercial-2	6.2	99.58	809	0.0068

E, PM removal efficiency; Δ*P*, pressure drop; PAN, polyacrylonitrile; QF, quality factor; T, transmittance.
$QF = -\ln(1 - E\%)/\Delta P$.

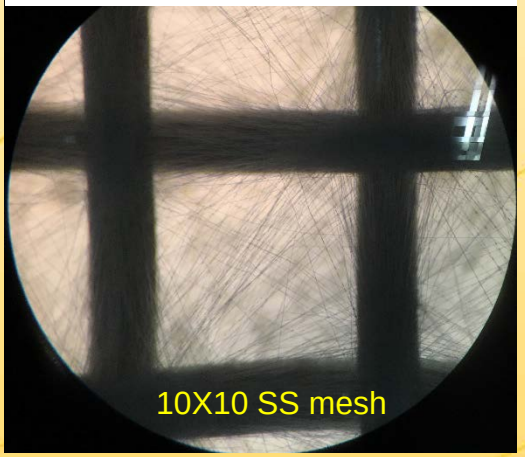
levels of transmittance. Figure 3e shows the schematic of the pressure drop measurement. The pressure difference across the air filter was measured. It is shown in Table 1 that at a face velocity of 0.21 m s^{-1}, the pressure drops of 85% and 75% transmittance air filters are only 133 and 206 Pa, respectively. This pressure drop is only <0.2% of atmosphere pressure, which is negligible. These levels of pressure drop are similar to that of a blank window screen without nanofibres (131 Pa). The Δ*P*

Lab-made transparent filter (U. of MN)

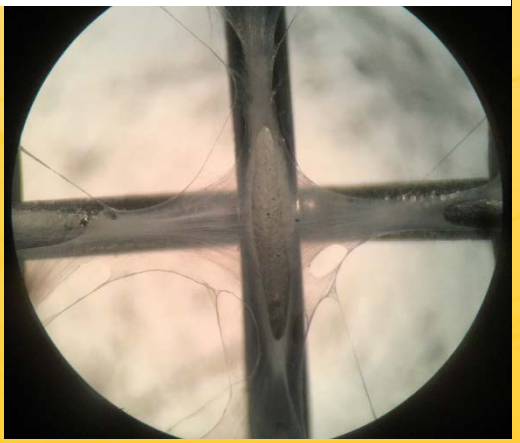




Optical microscopic image



Damaged nanofiber layer

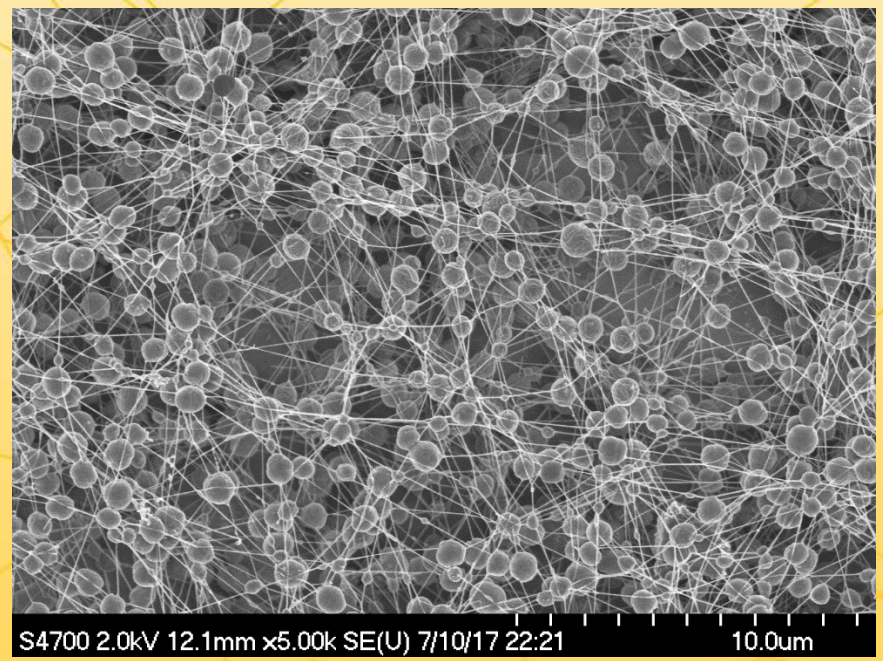


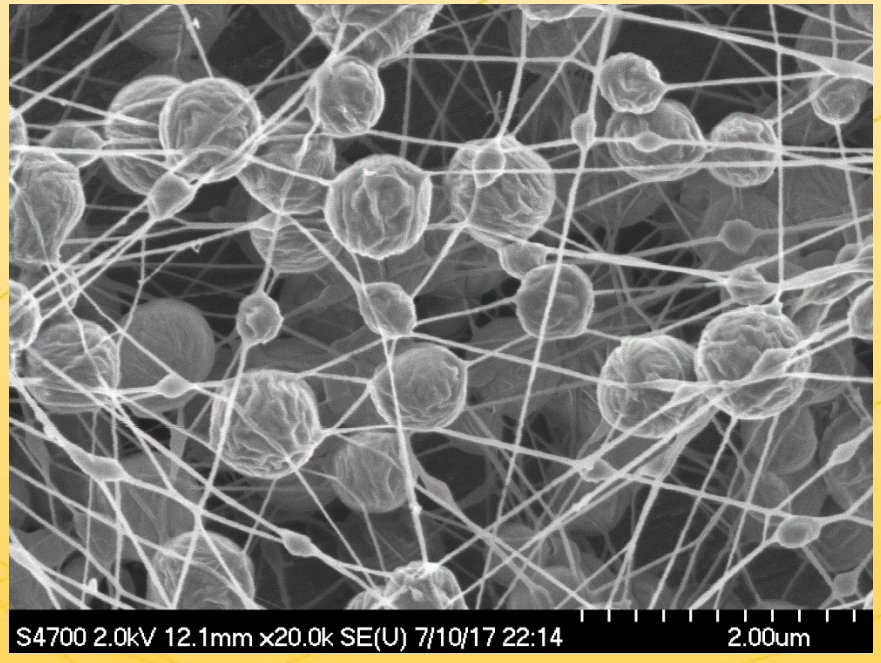
Conclusions (Transparent filter)

- Transparent filter can be manufactured by depositing nanofiber layer on metal wire mesh.
- Nanofiber layer alone can be damaged easily, so hard to be used a traditional way of filtration.
- It is not clear in the literature but we can “suspect” that
  1. The filtration efficiency will decrease dramatically as increasing air flow, especially high transparency filter.
  2. Low transparency filter can be easily damaged by air flow due to its high pressure drop.
  3. With severe air contamination, the transparent filter would be dirty and lose its transparency so easily.

High Loading Filter Media

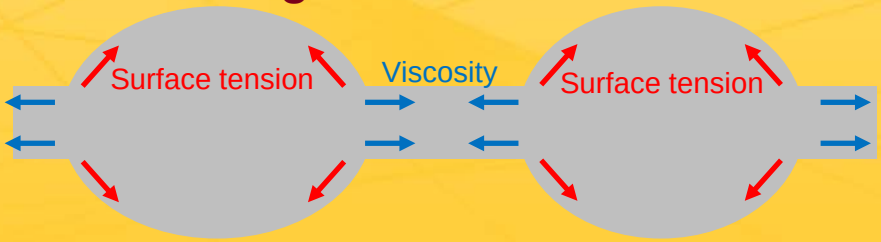
Nanofiber with beads





- PEO (MW=1,000,000 g/mol) 4g + DI water 100 ml
- Syringe needle: Blunt tip, I.D. 1.651 mm, Length 3.8 cm
- Solution feeding rate = 0.3 ml/hr, V = 7 kV, D = 10 cm

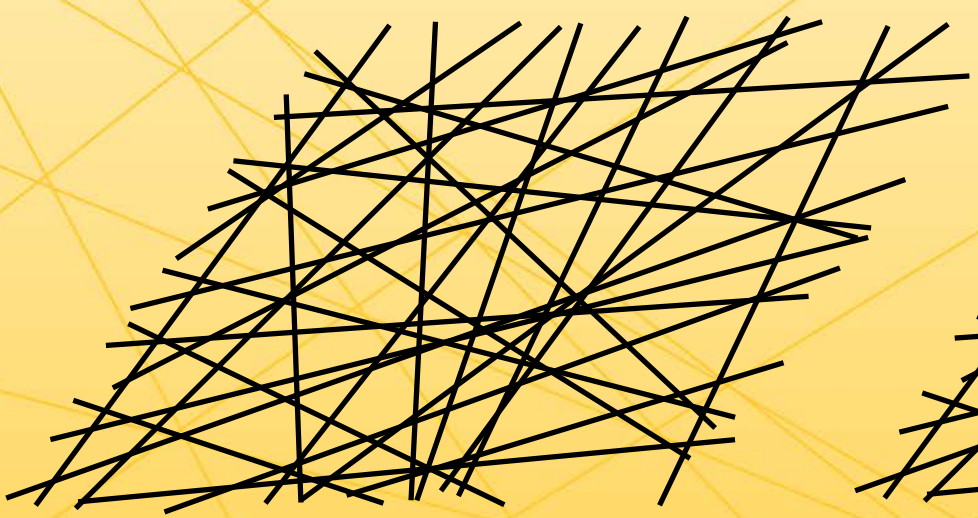
Bead forming

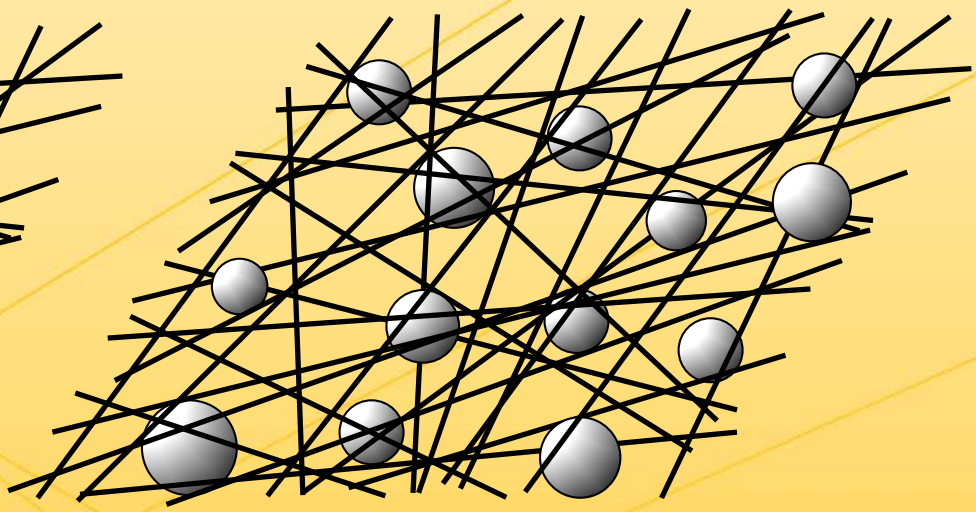


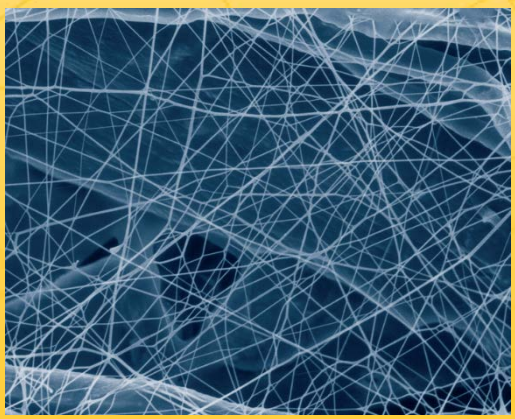
Beaded nanofiber filter media

w/o beads

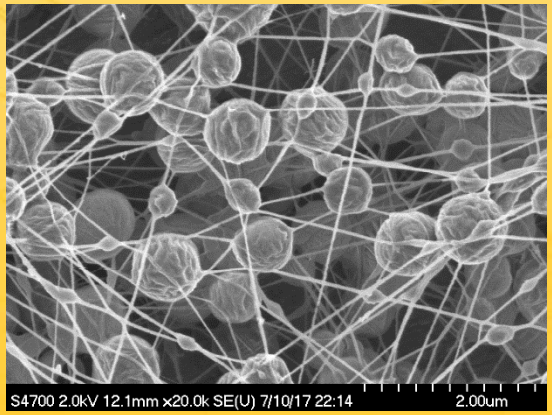
with beads







- 2D structure
- Surface loading
- High ΔP
- Low loading cap.



- 3D structure
- Depth loading
- Low ΔP
- High loading cap.

SEM image from Donaldson.com

Publication about nanofiber filters with beads

Separation and Purification Technology 75 (2010) 340–345

Contents lists available at ScienceDirect

Separation and Purification Technology

journal homepage: www.elsevier.com/locate/seppur

Morphology optimization of polymer nanofiber for applications in aerosol particle filtration

Ki Myoung Yun[a,b], Adi Bagus Suryamas[a], Ferry Iskandar[a,d], Li Bao[c], Hitoshi Niinuma[c], Kikuo Okuyama[a,*]

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[b] Department of Chemical and Biomolecular Engineering, KAIST, 335 Gwahangno, Yuseong-gu, Daejeon 305-701, Republic of Korea
[c] Nippon Muki Co., Ltd., 415 Sakuneya, Yuki, Ibaraki 307-0046, Japan
[d] Department of Physics, Institut Teknologi Bandung, Jalan Ganesa 10, Bandung 40132, Indonesia

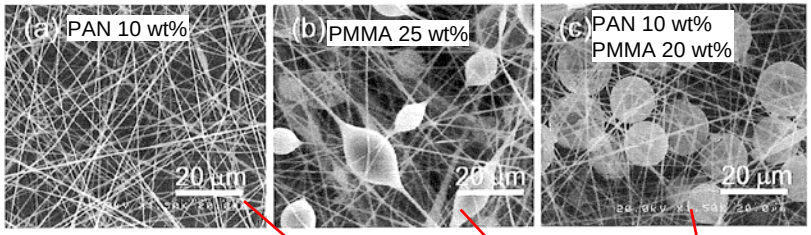
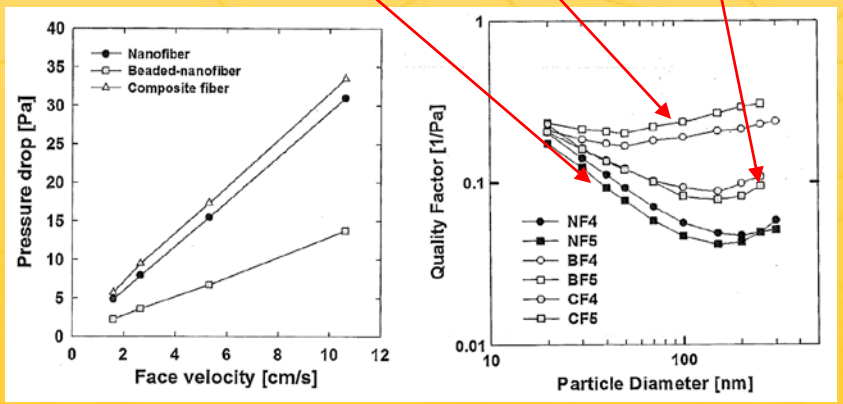


Fig. 4. SEM images of nanofiber (a), beaded-nanofiber (b), and composite particle/nanofiber (c) filter mats.



Journal of Colloid and Interface Science 441 (2015) 121–129

Contents lists available at ScienceDirect

Journal of Colloid and Interface Science

www.elsevier.com/locate/jcis

Porous bead-on-string poly(lactic acid) fibrous membranes for air filtration

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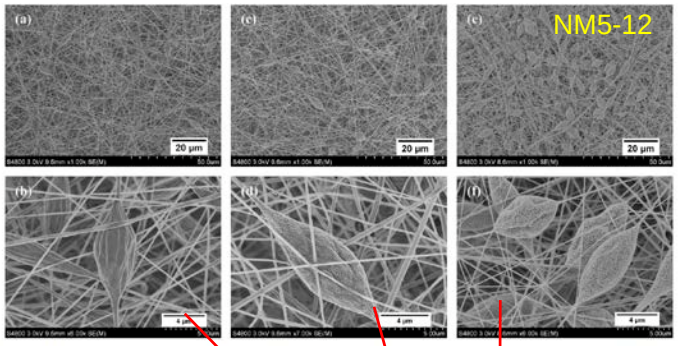
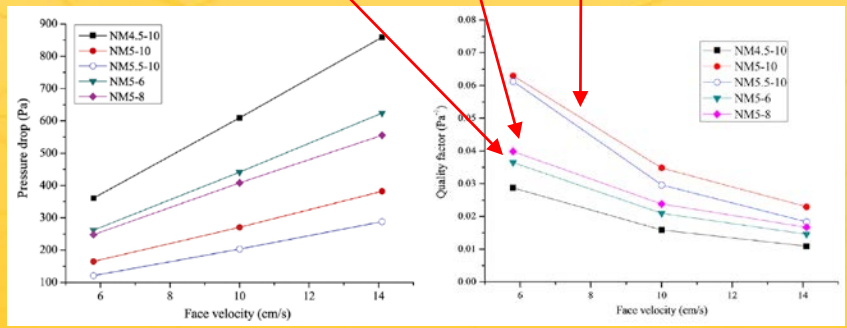
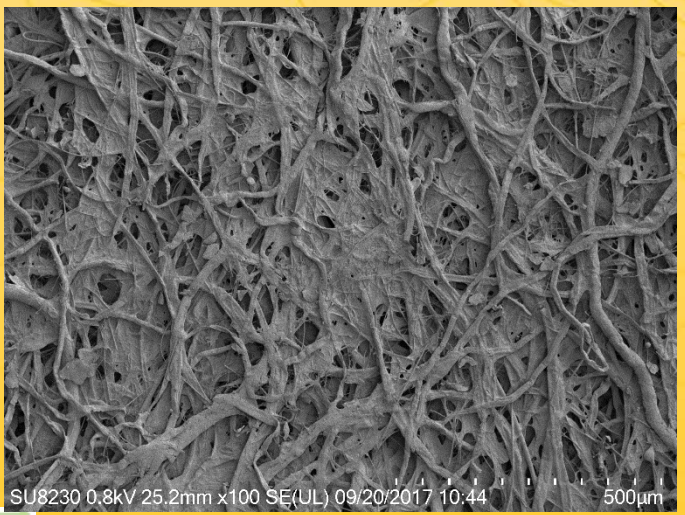
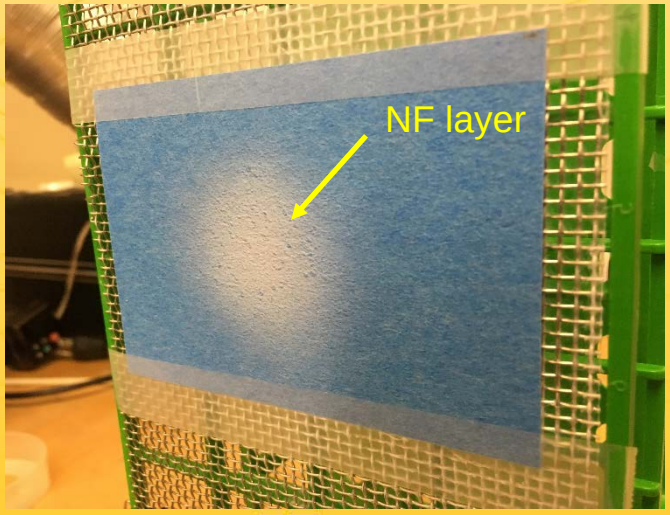


Fig. 5. SEM images of PLA fibers electrospun from 5 wt% PLA solutions with different weight ratios of DCM/DMAC: (a) 6/1, (c) 8/1, and (e) 12/1. Highly magnified images corresponding to the membranes are shown in (b), (d), and (f), respectively.

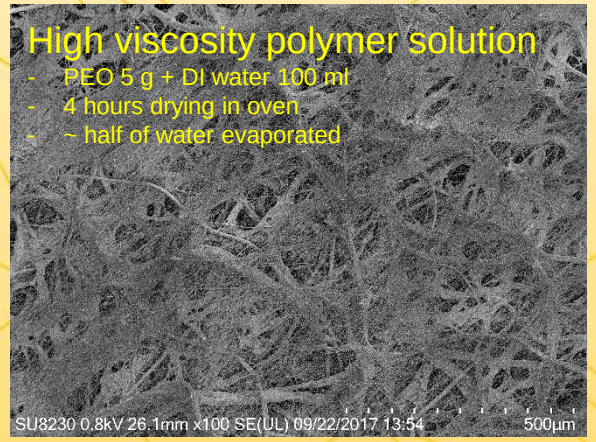


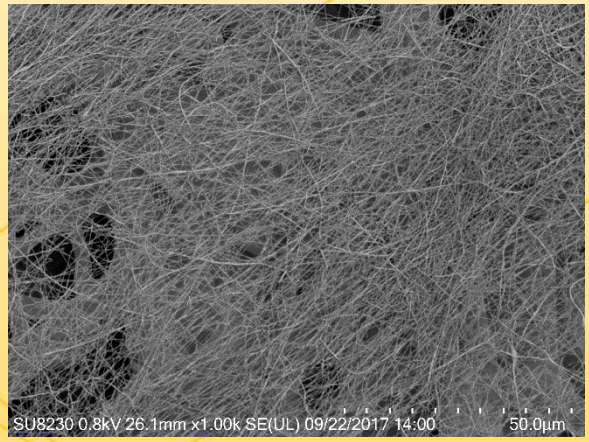
Cellulose filter media for NF deposition (Substrate)

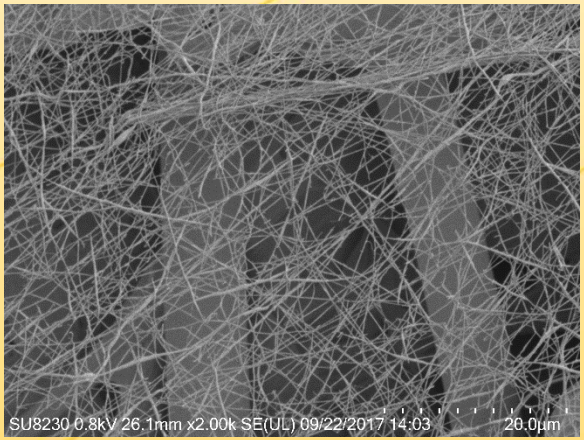


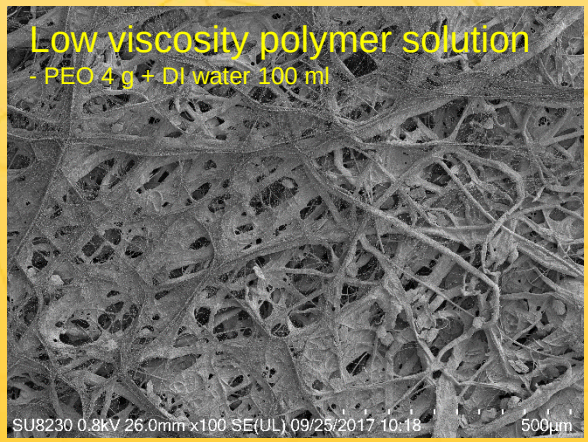


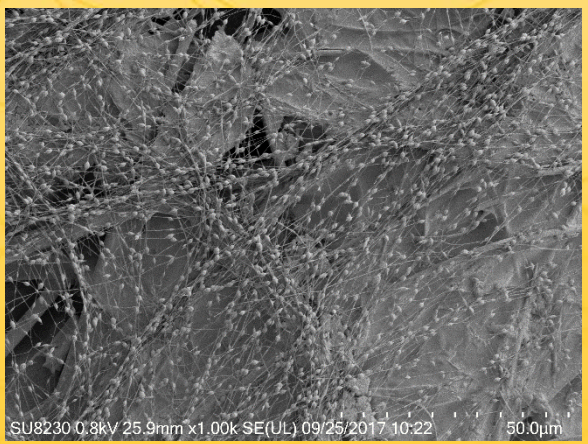
Nanofiber filter samples (NF vs. Beaded NF)

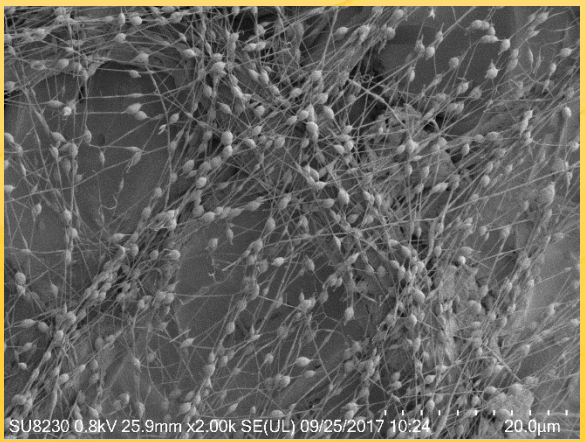




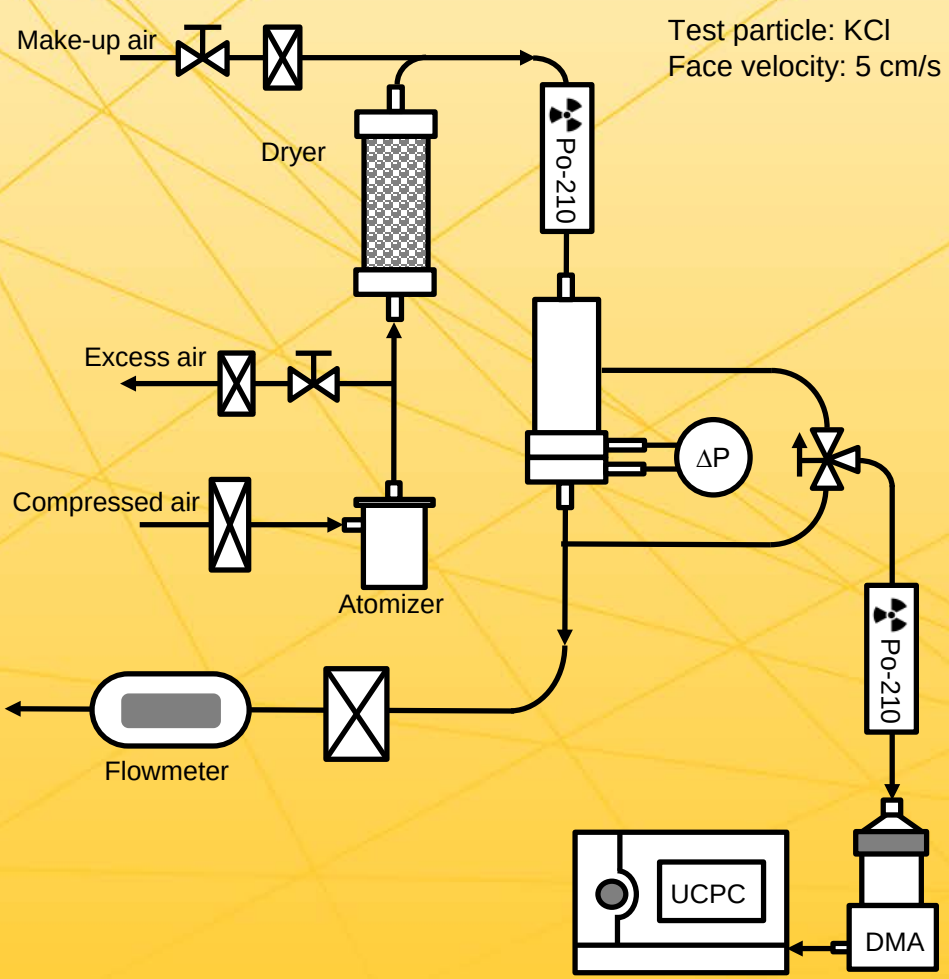




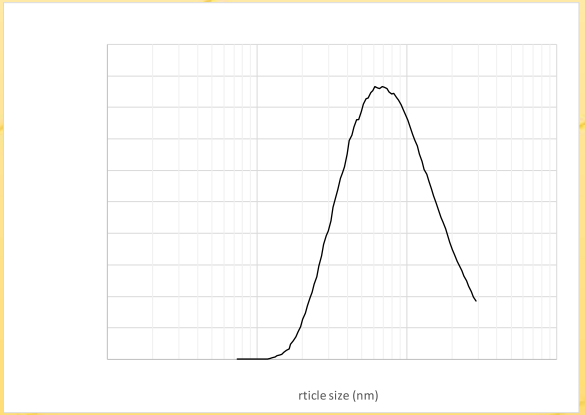


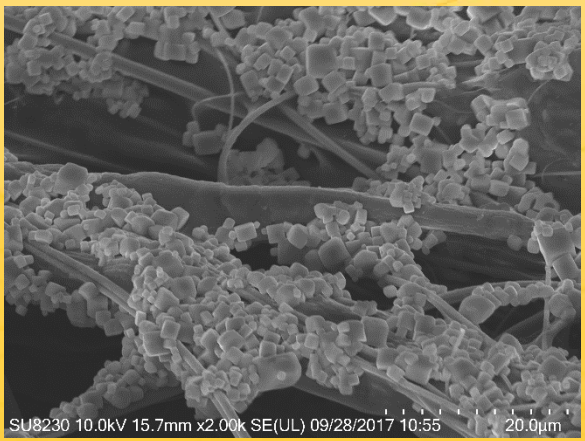


Nanofiber filter efficiency & loading test

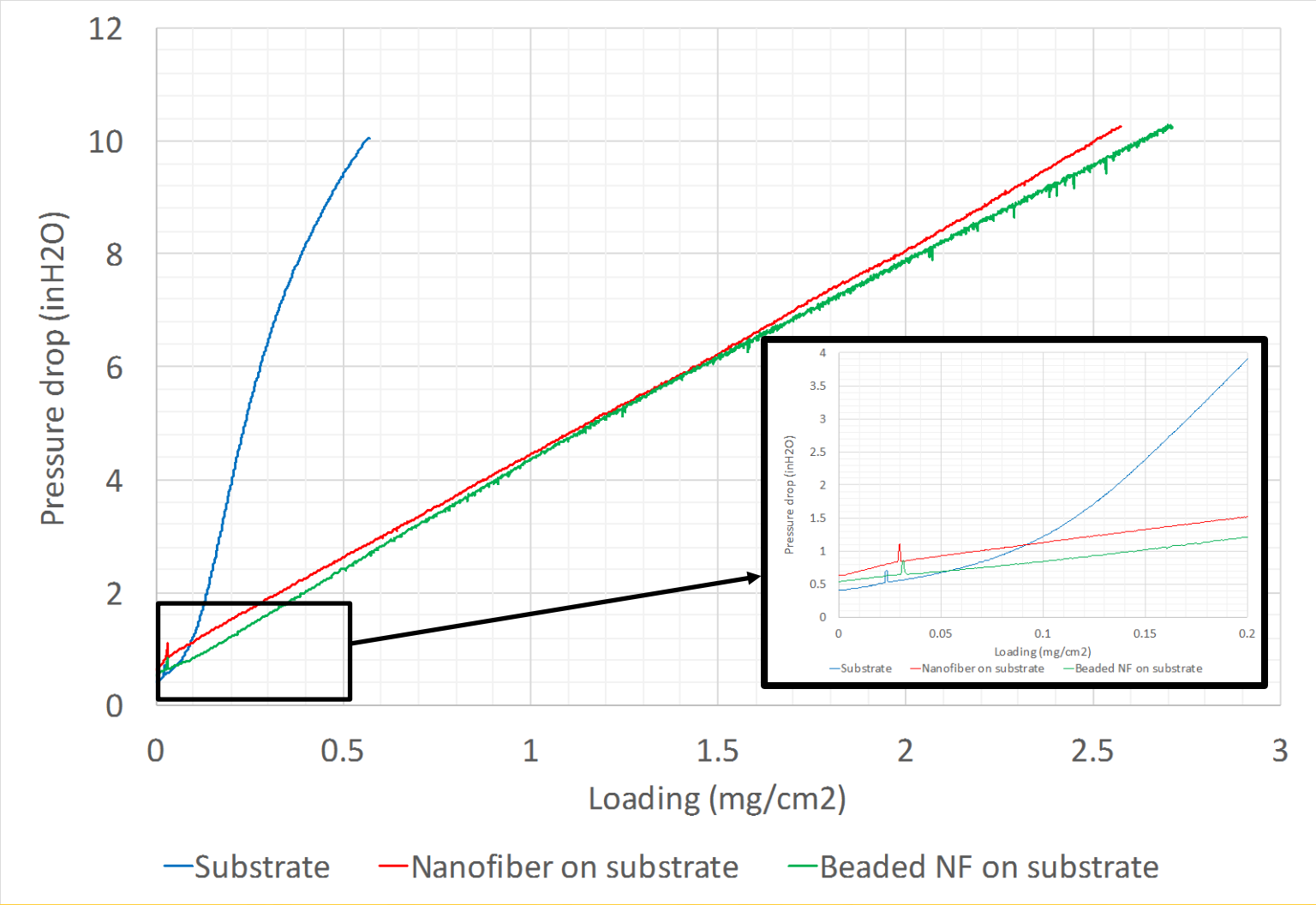


Test particle: KCl
Face velocity: 5 cm/s

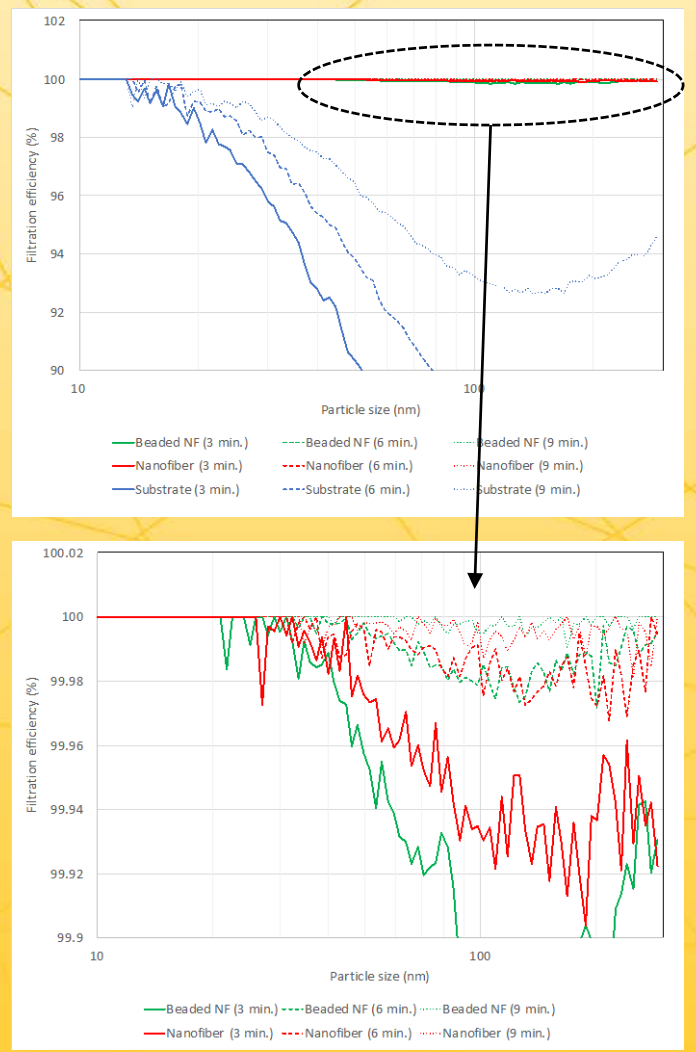


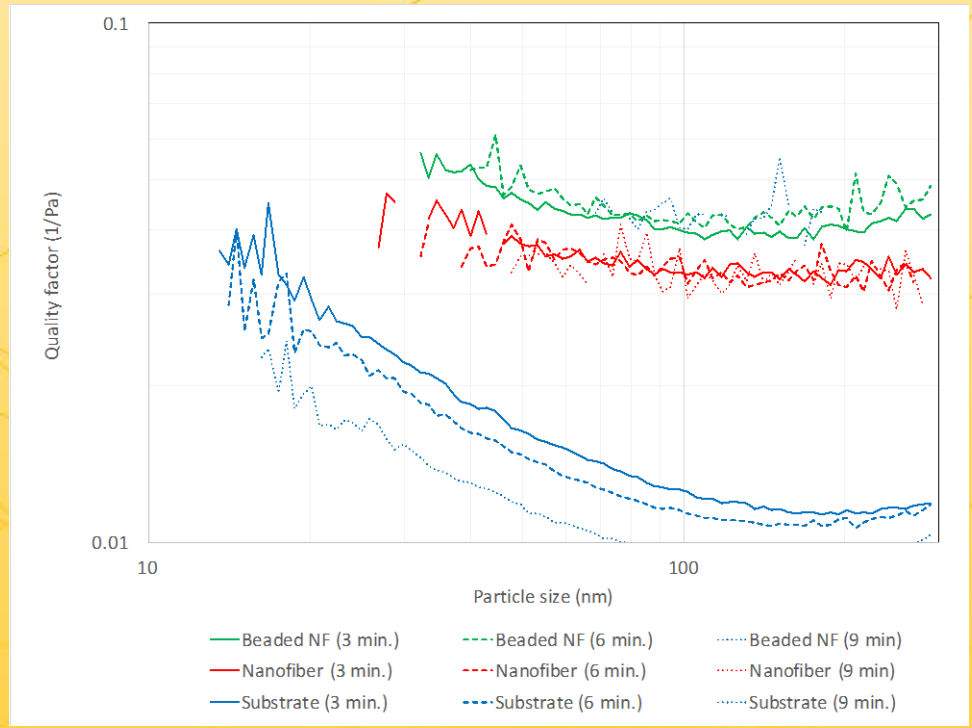


Nanofiber filter loading test result (ΔP)



Nanofiber filter loading test result (η & QF)





Conclusions (High loading filter media)

- Polymer beads on nanofibers can be generated during electrospinning with low viscosity and high surface tension of polymer solution.
- These polymer beads can be used as spacers to improve particle loading capacity of nanofiber filters.
- Particle loading test result shows
  1. NF and Beaded NF filters show slower ΔP increase than substrate only, even though they have higher initial ΔP.
  2. Beaded NF filter shows about 30% higher Quality Factor (QF) than Nanofiber filter, and the optimum beaded NF design needs to be investigated.