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Production and Properties of Nanofiber Nonwovens for Industrial Applications

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OUTLINE

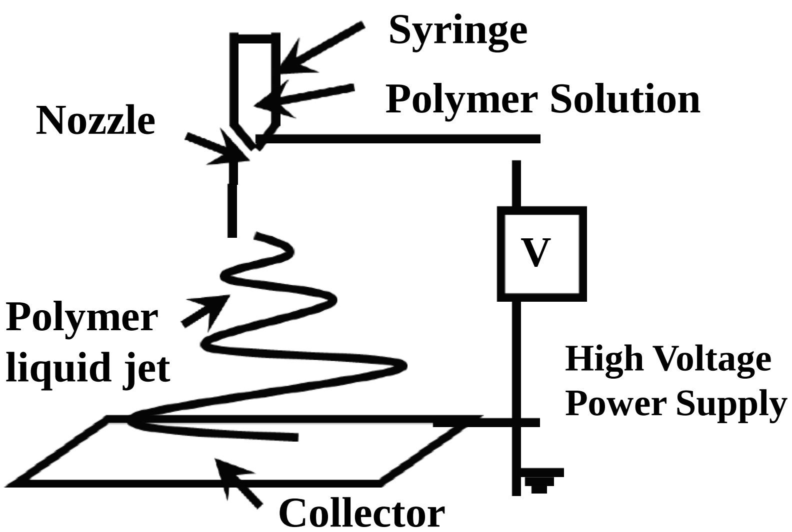
1. Production of nanofibers by “Electro Bubble Spinning Method”

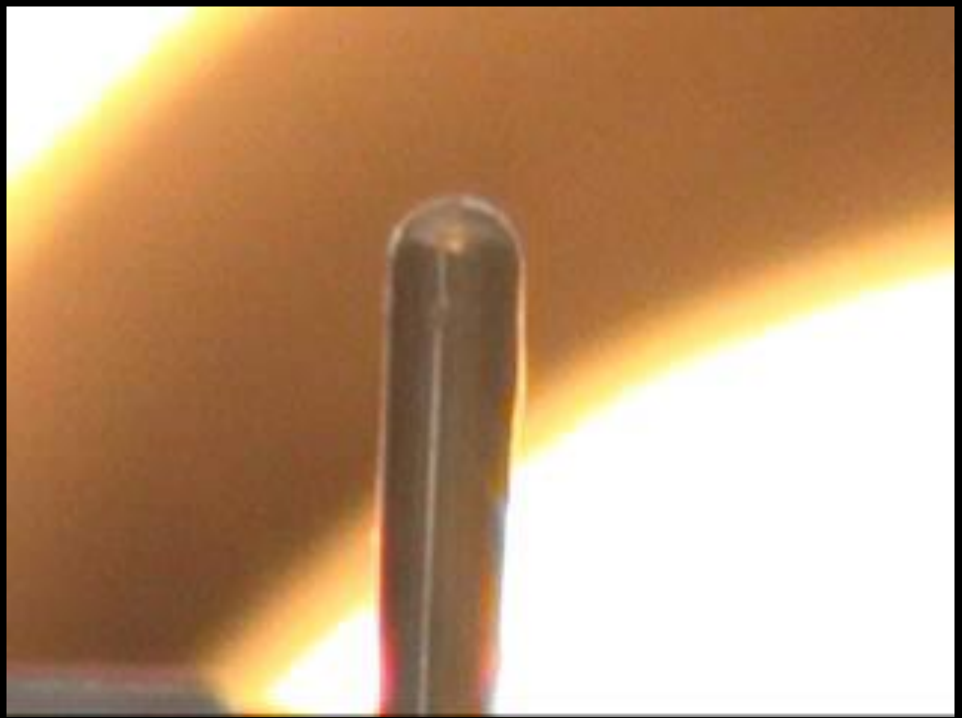
2. Properties of nanofibers overlaid nonwovens

3. Properties of polymer/silica composite nanofibers

4. Industrial applications for nanofiber nonwovens

Electrospinning (Conventional method)





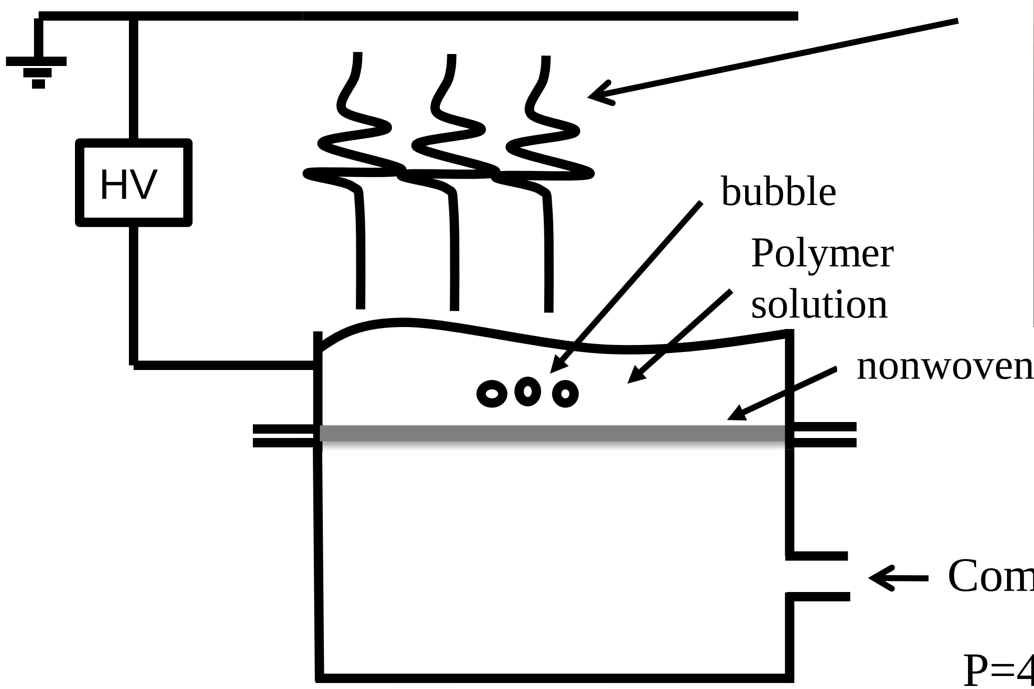
Video of the Polymer Jet

Why has electrospinning not been widely used for the production of nanofiber?

1. **Inefficient nozzle based electrospinning is still predominant**
2. **High maintenance due to the clogging of nozzles**
3. **Nonuniformity of nanofiber layer thickness**
4. **High production cost**

Electro Bubble Spinning (EBS)

Principle of EBS



Polymer Liquid Jets

$$P=4\times\gamma\times\cos\theta/D$$

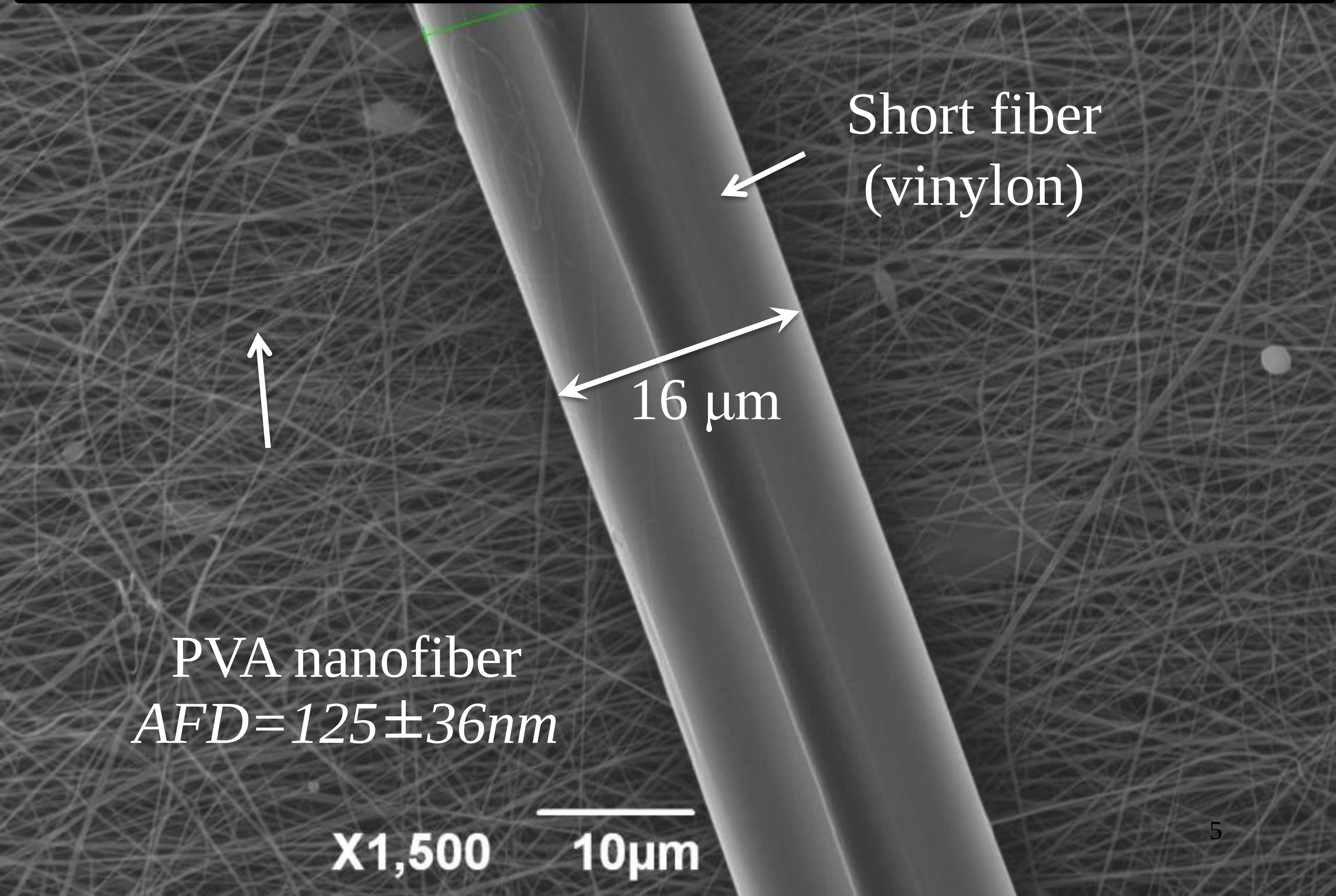
γ: surface tension of the polymer solution

θ: contact angle of a porous materials and a polymer solution

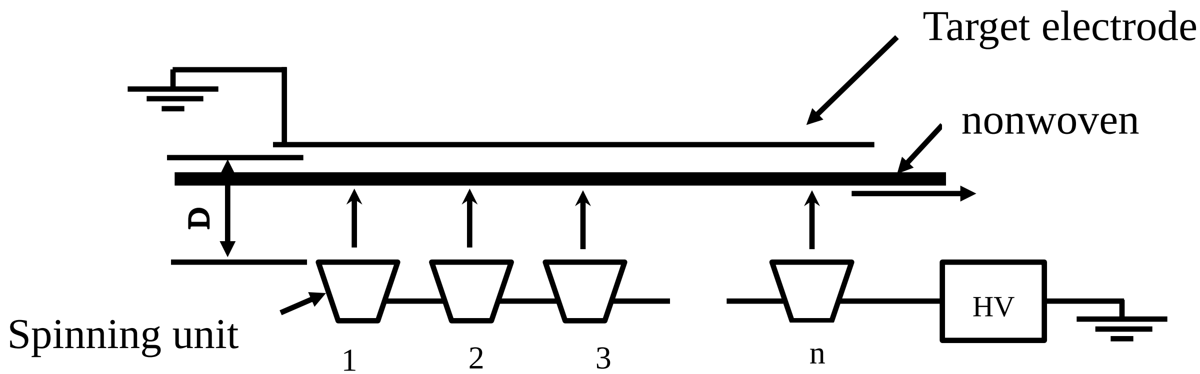
D: bubble point diameter of the porous materials

(Japanese Patent 3918179)

Comparison of fiber diameter of nanofiber and conventional fiber



Improvement of nanofiber production



Speed up of production line → more spinning units

Advantages of EBS

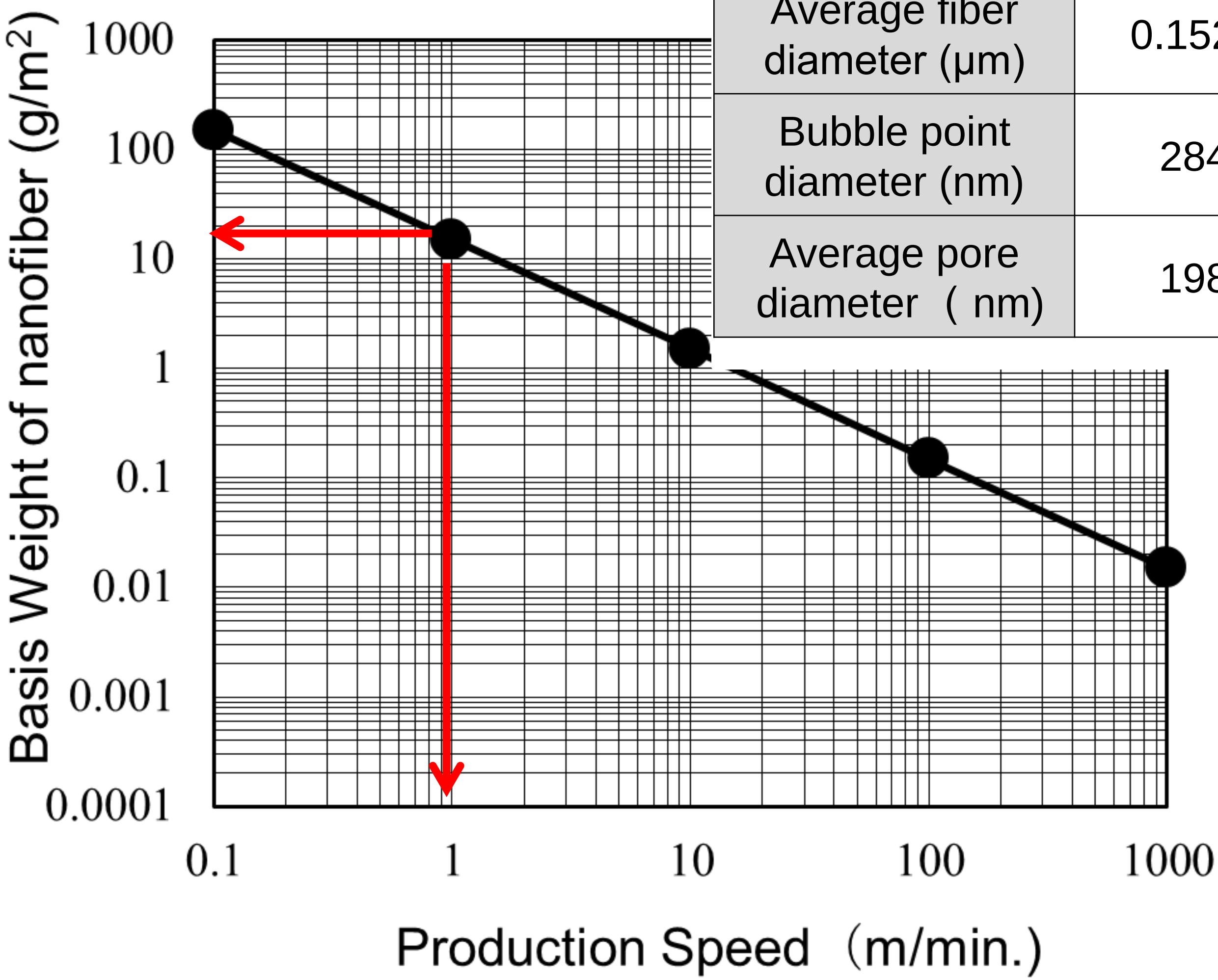
1. High production throughput
2. Low variation in basis weight of nanofiber
3. Easy maintenance
4. Ecellent cost performance

Nanofiber Production Line based on the EBS method

Line length : 20M
Spinning area : 16M
Width of the Web : 1,600mm

Production Speed

	AV.	SD	CV(%)
Basis weight of nanofiber (g/m^2)	5.75	0.27	4.7
Average fiber diameter (μm)	0.1520	0.0087	5.7
Bubble point diameter (nm)	284	9	3.2
Average pore diameter （nm)	198	7	3.5



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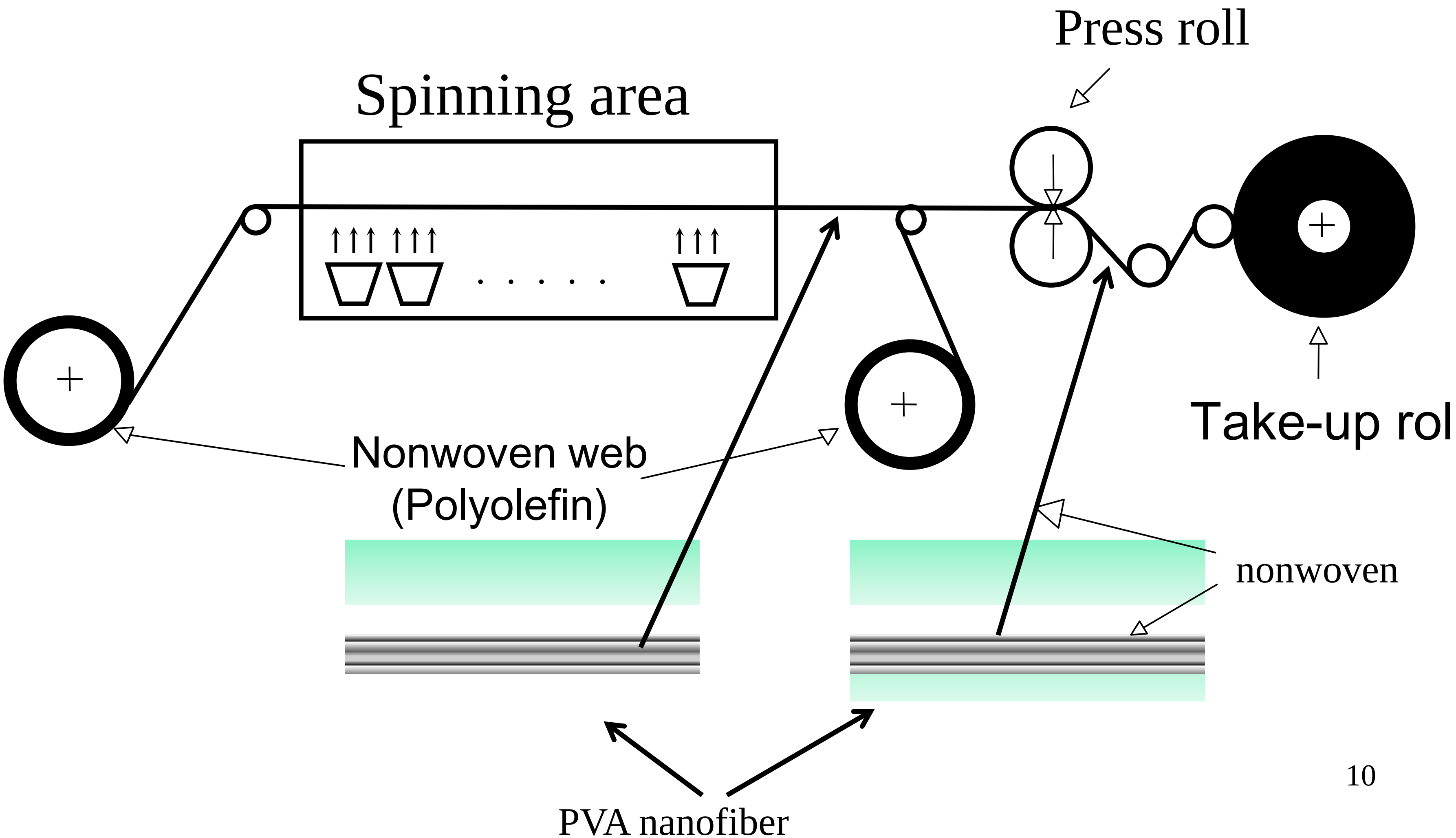
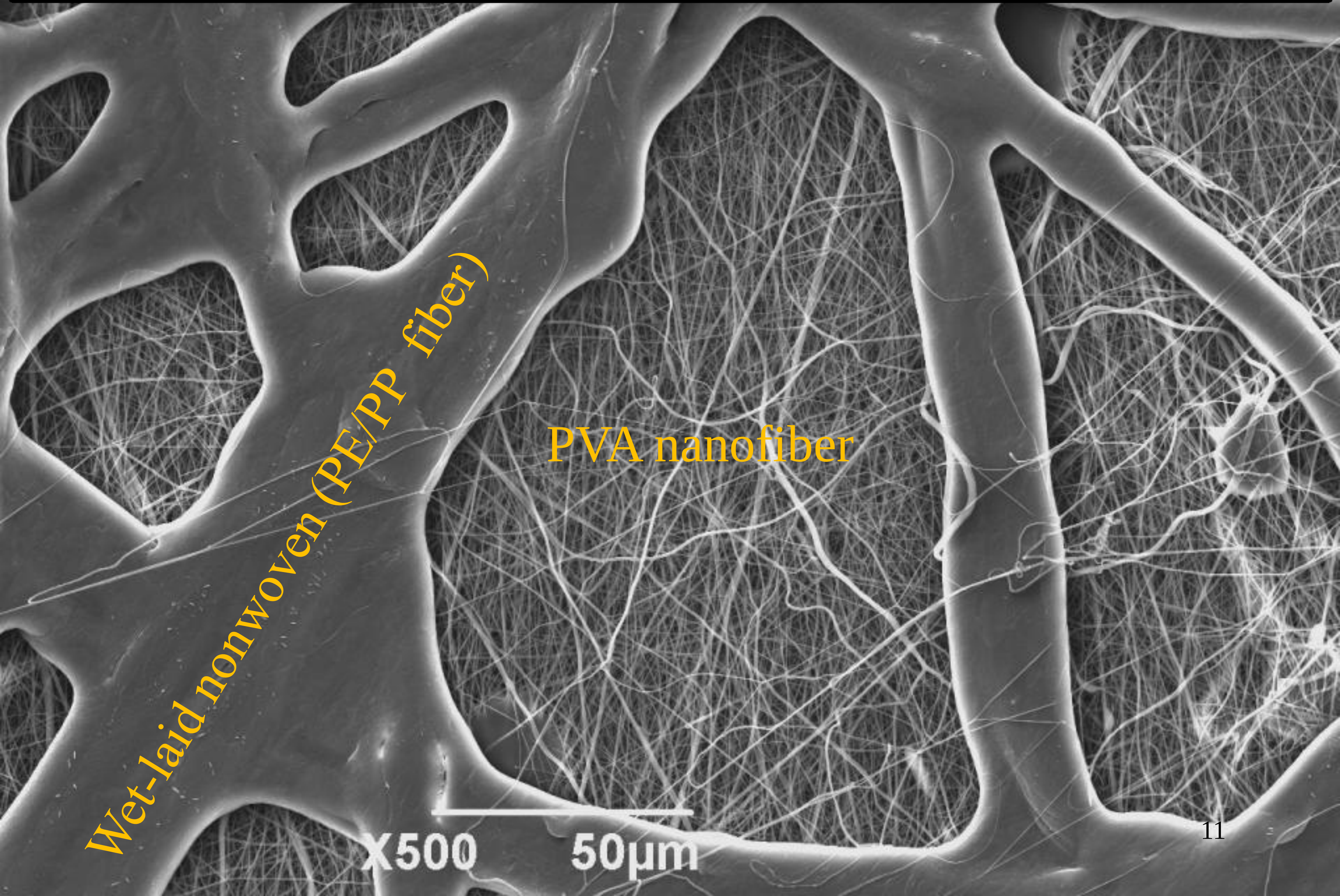
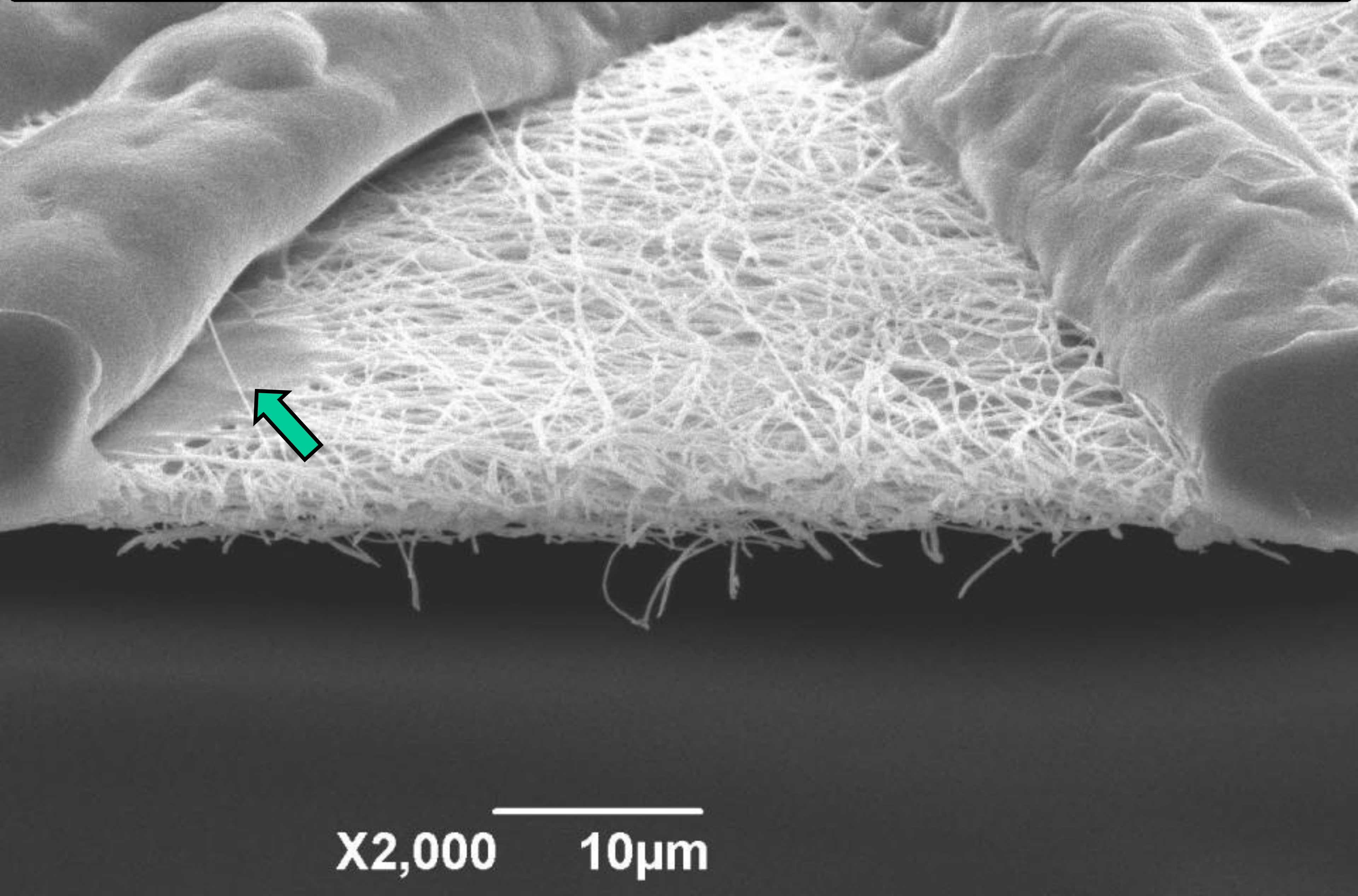
Composites of 2 and 3 layers can be produced



Nanofiber overlaid nonwoven (Top View)

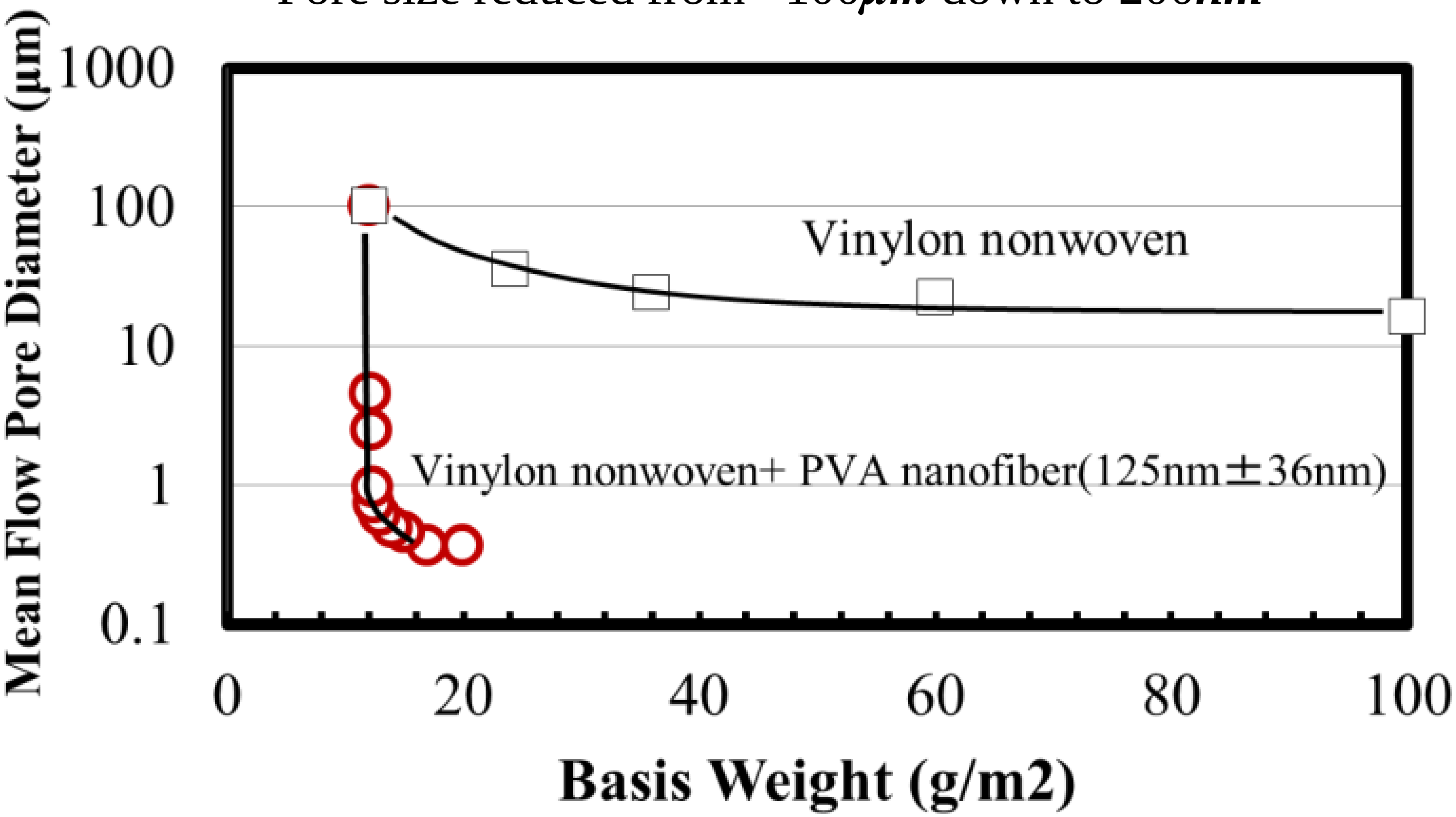


Nanofiber overlaid nonwoven (Side View)



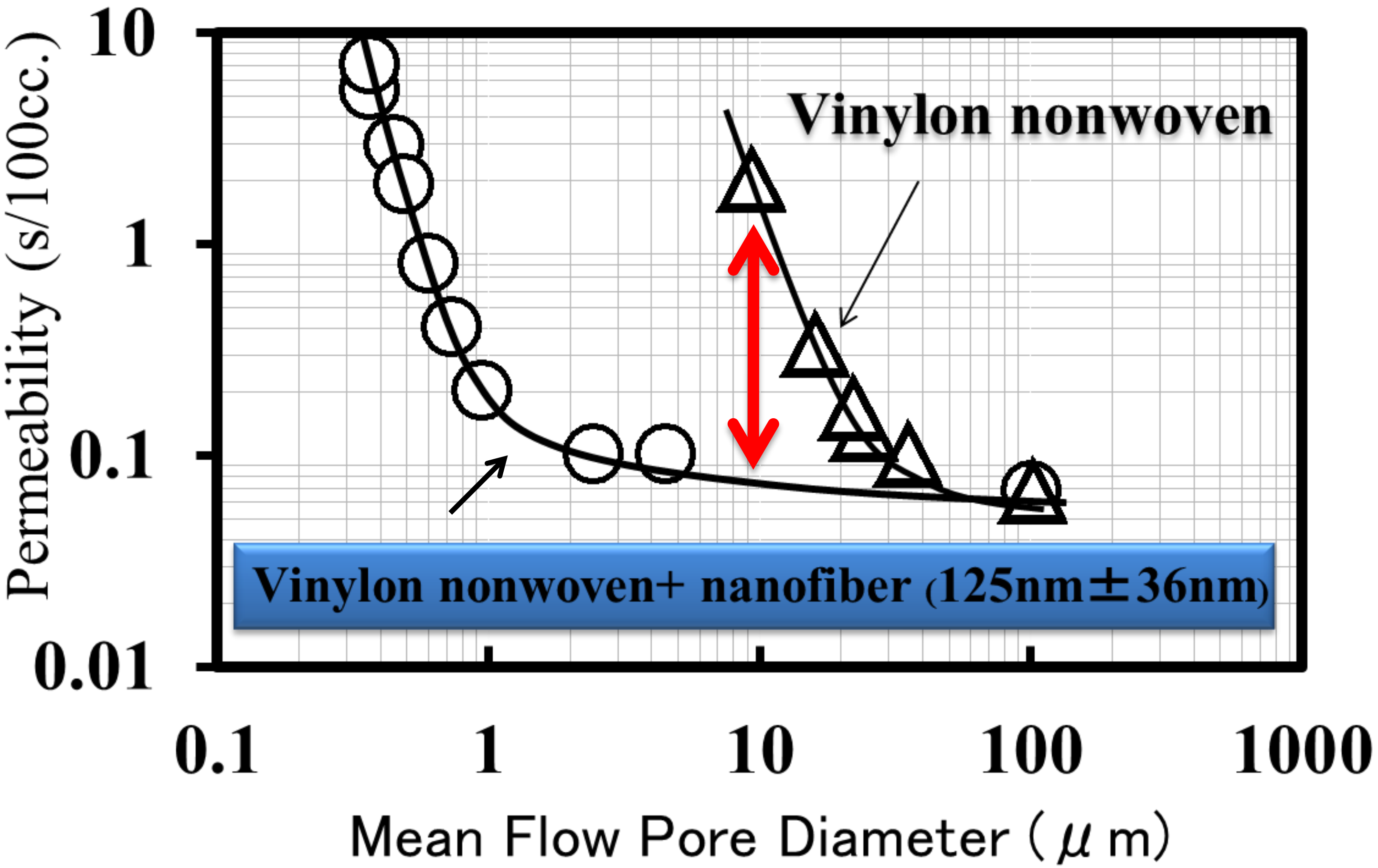
Comparison of Mean Flow Pore Diameter

Pore size can be controlled by the amount of nanofiber overlaid
Pore size reduced from ~100***μm*** down to 200***nm***



Comparison of Permiability

Air permeability of nanofiber web is 1/10 of microfiber web at same pore diameter (10μm)



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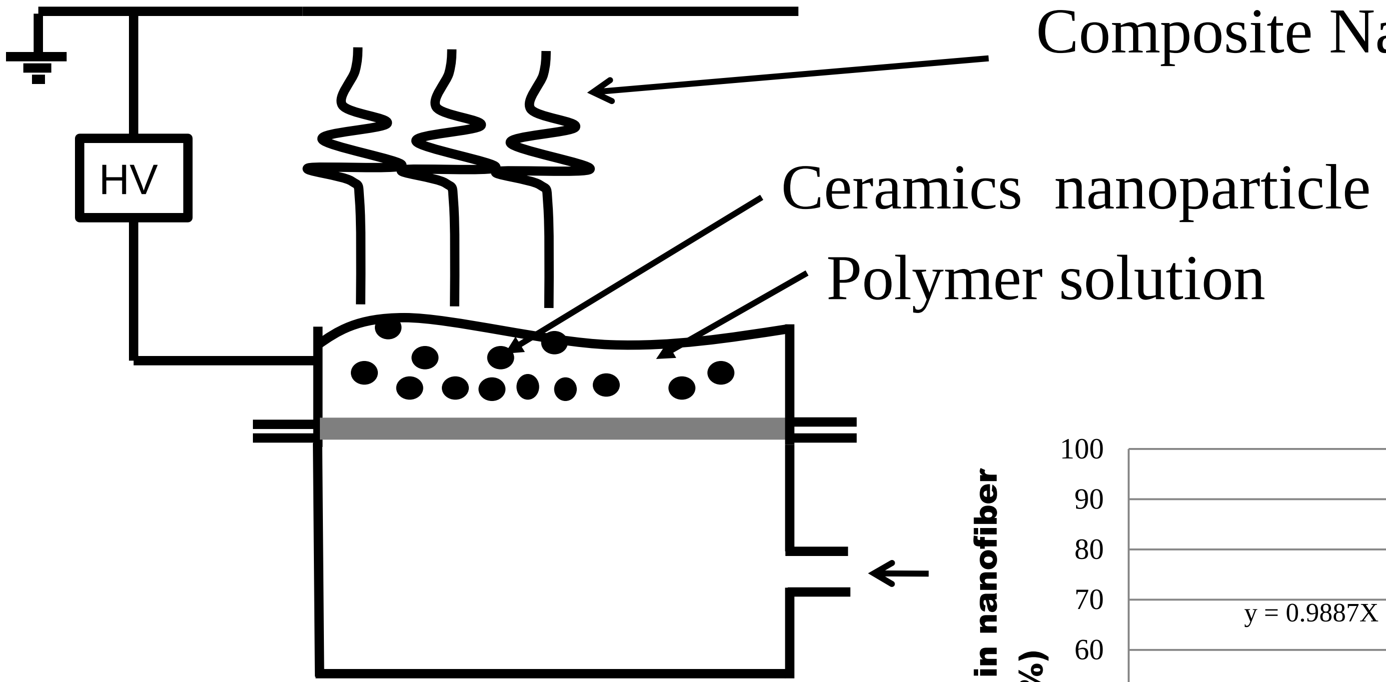
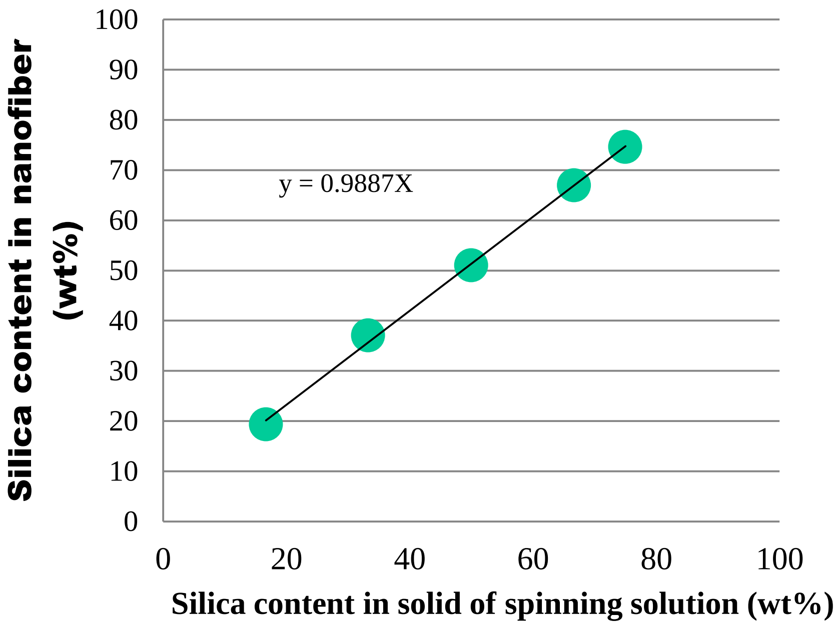
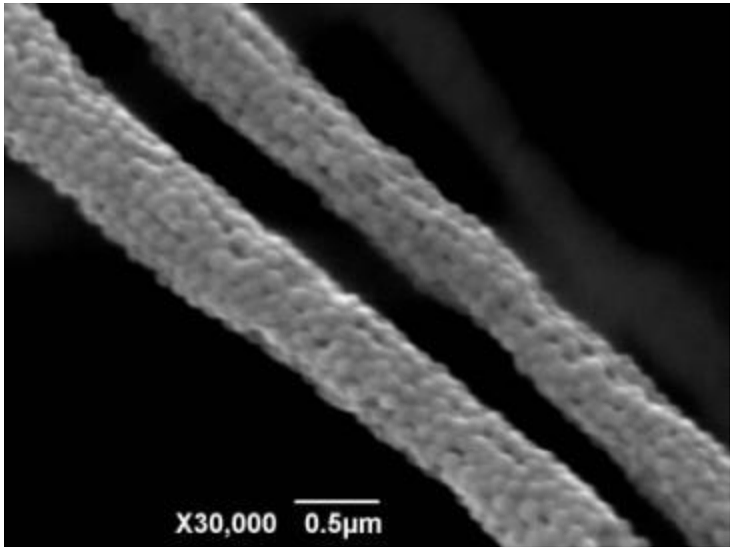
Production of Composite Nanofibers

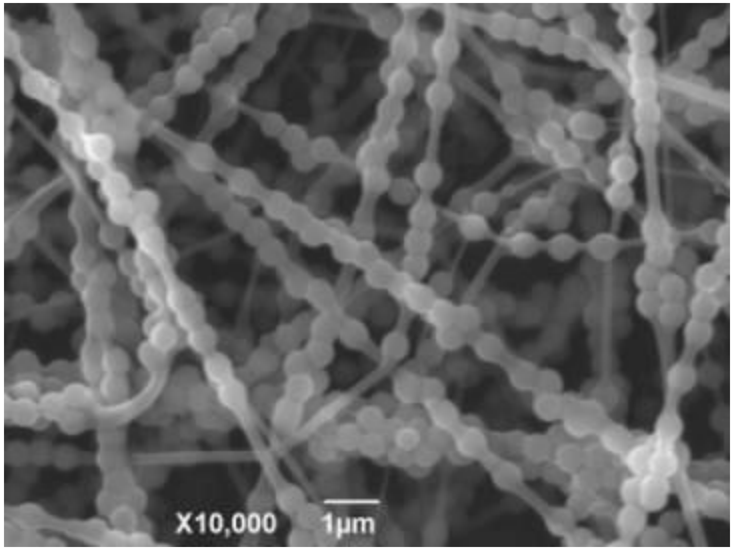




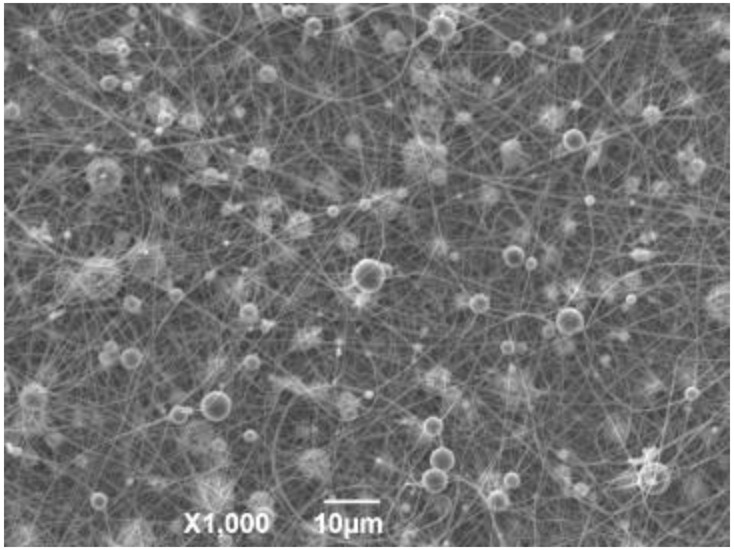
Composite Nanofibers of PVA/ceramics



PVA/SiO2(100nm) composite nanofiber

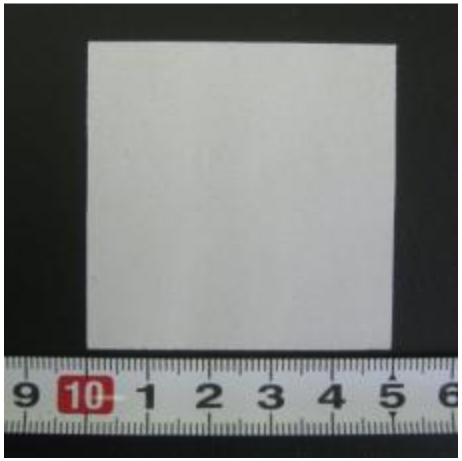
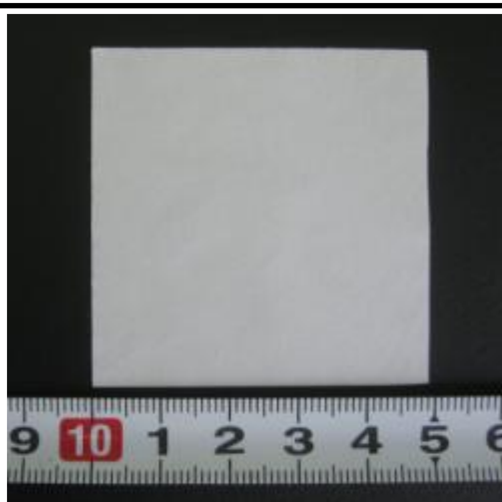
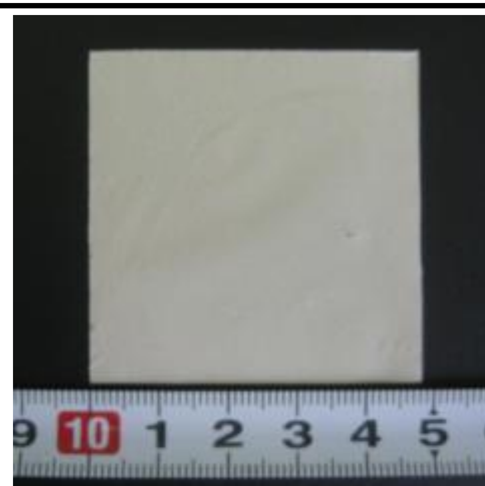
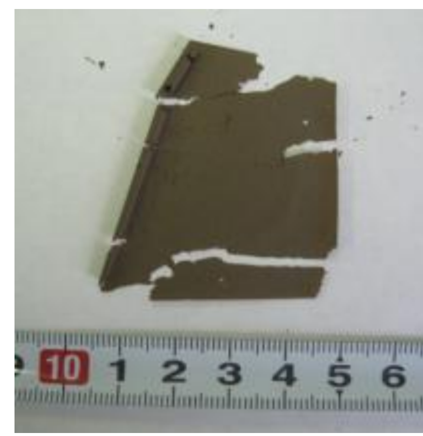


PVA/SiO2(500nm) composite nanofiber



PVA/Al_2O_3(4.7 μm) composite nanofiber

Heat resistance of PVA/SiO_2 nanofiber

	As spun	200℃×1Hr	300℃×1Hr
PVA nanofiber			
PVA/SiO_2 nanofiber	 Bublbe Pore ：0.449μm Mean Flow Pore ：0.2768μm	 Bubble Pore ：0.456μm Mean Flow Pore ：0.2841μm	

Heat resistance of PVDF/SiO_2 nanofiber

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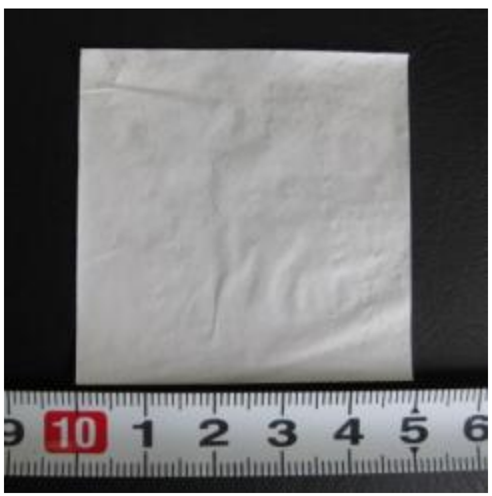
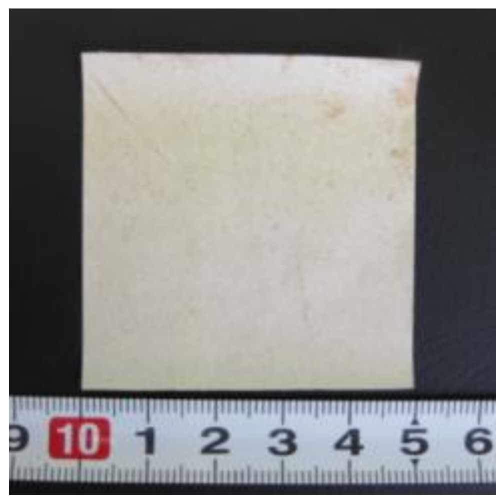
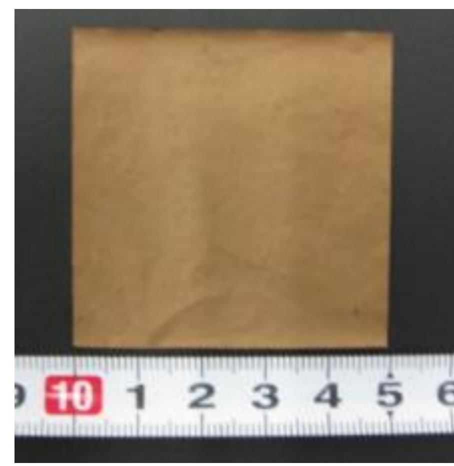
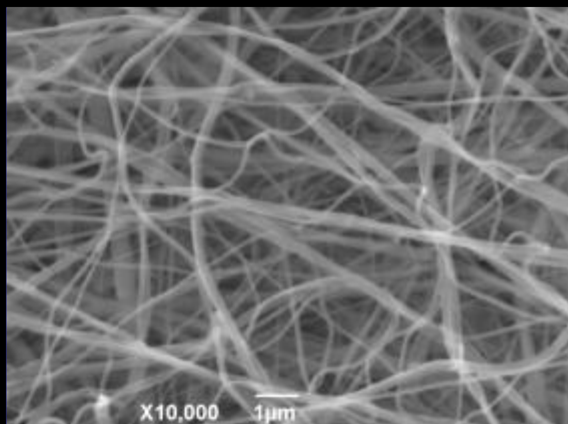
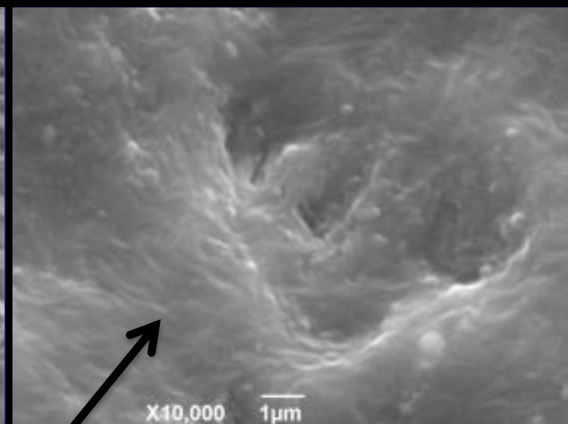
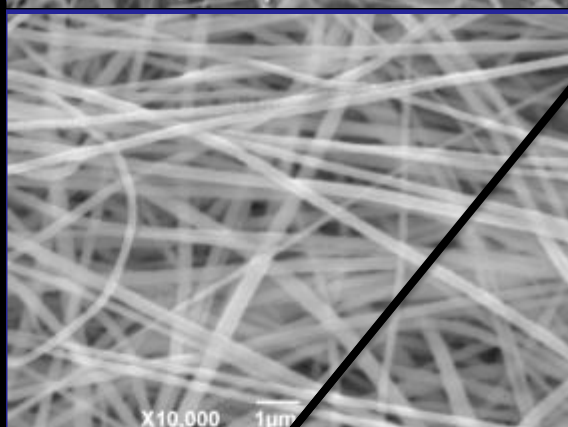
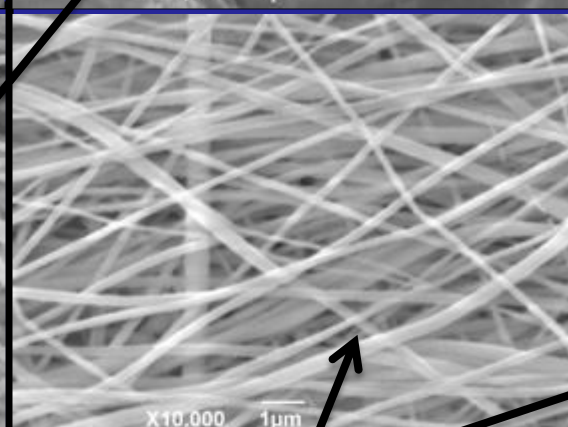
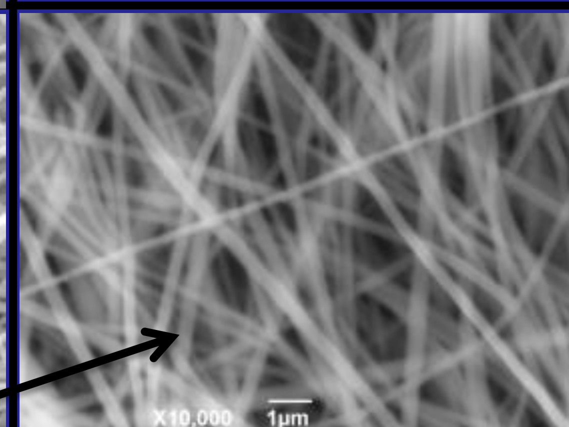
	As spun	200℃×1Hr	300℃×1Hr
PVDF nanofiber			—
PVDF/SiO_2 nanofiber	 Bubble Pore : 0.805μm Mean Flow Pore : 0.473μm	 Bubble Pore : 0.706μm Mean Flow Pore : 0.414μm	

Morphology changes of PVDF/SiO_2 nanofibers

	as spun	200℃× 1 Hr	300℃× 1 Hr
PVDF nanofiber			
PVDF/SiO_2 nanofiber			

Melted

Maintaining nanofiber structure

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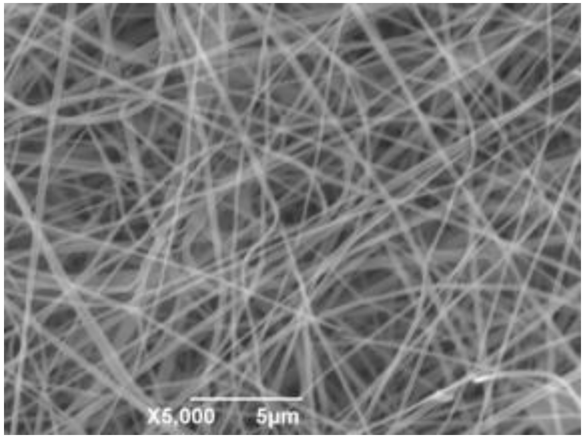
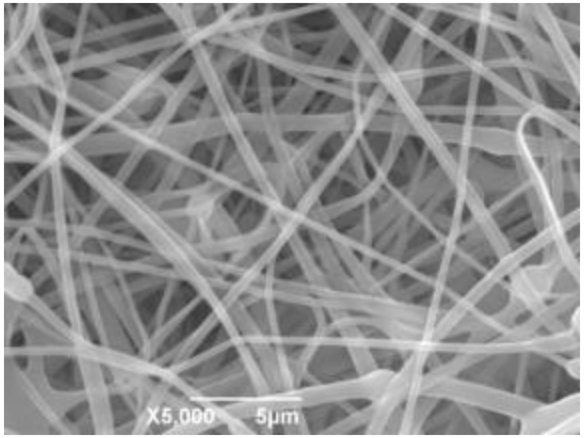
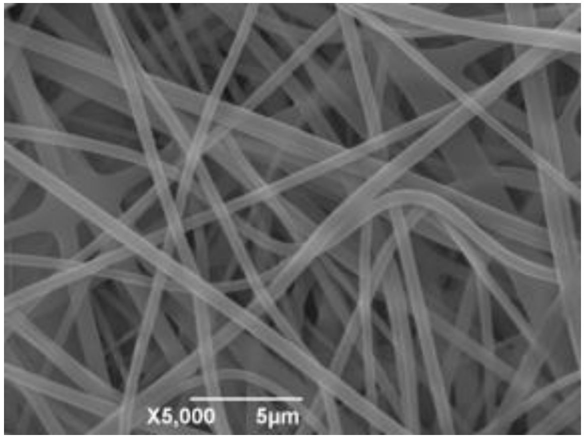
Control of Diameter of PVA nanofiber



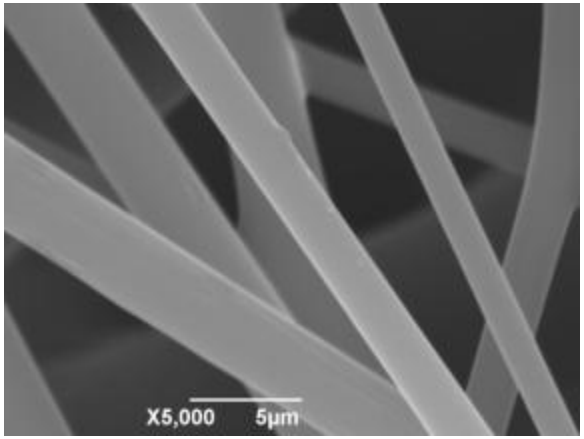
222±79nm



448±216nm

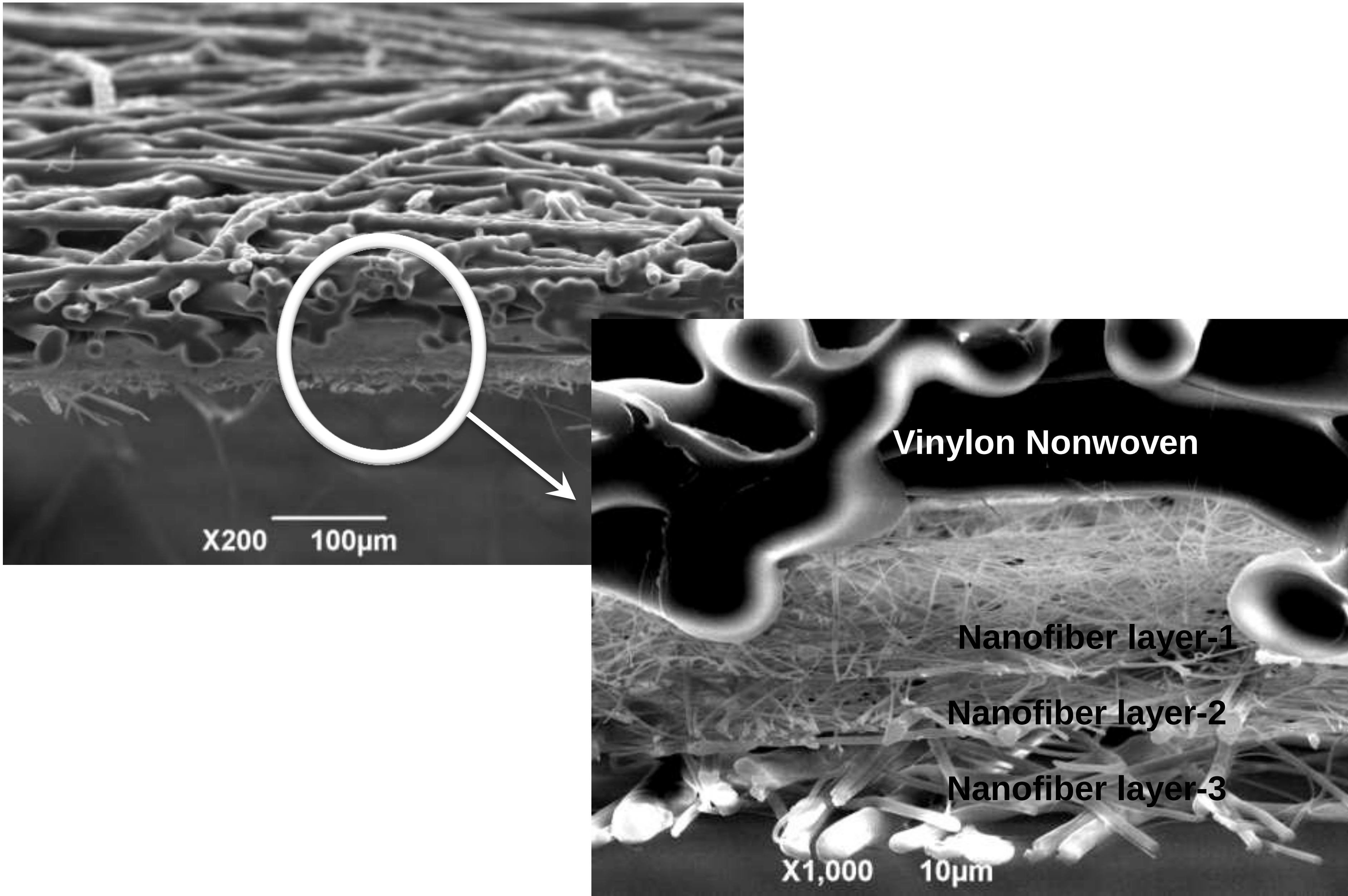


597±324nm

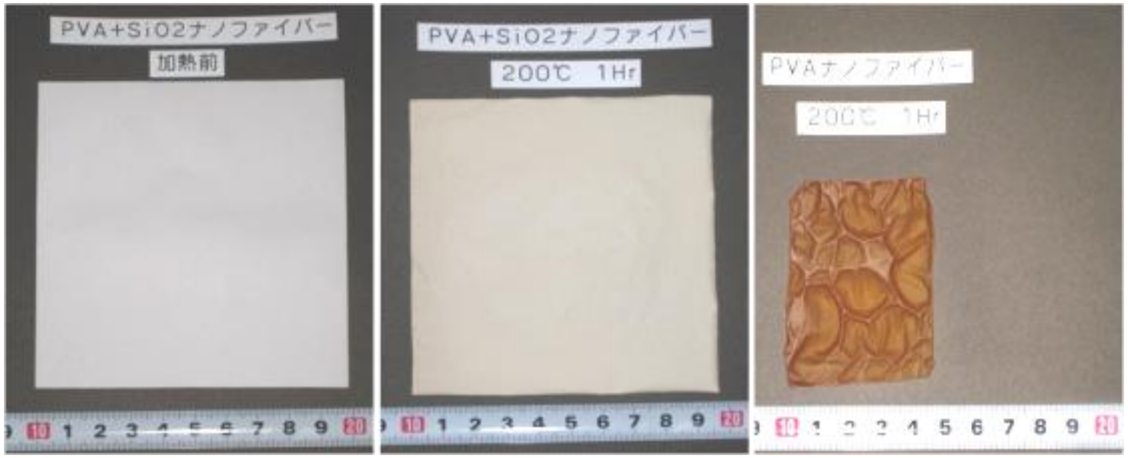


1,711±724nm

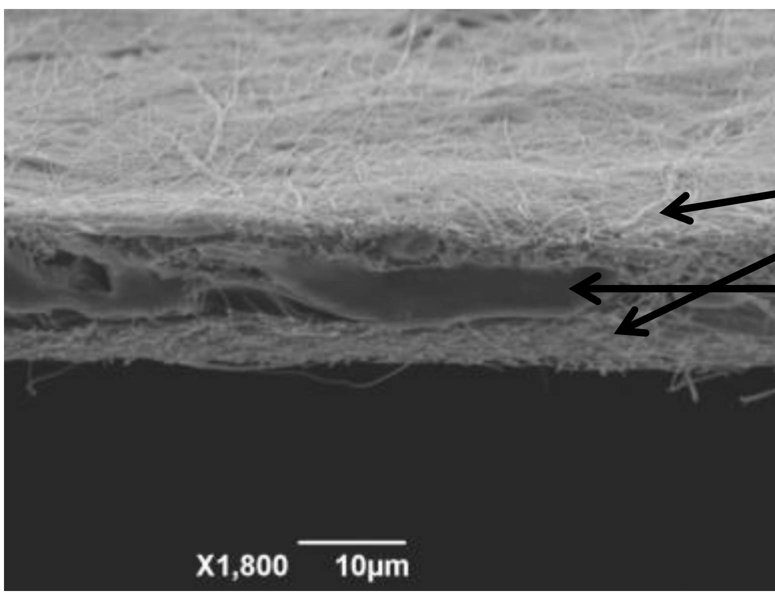
Cross Section View of Multi-layered Nanofiber Web



Application Trial of High Performance Separator for LIB



⇒ PVA nanofiber with nanosilica shows improved heat resistance



Separator of three-layer structure

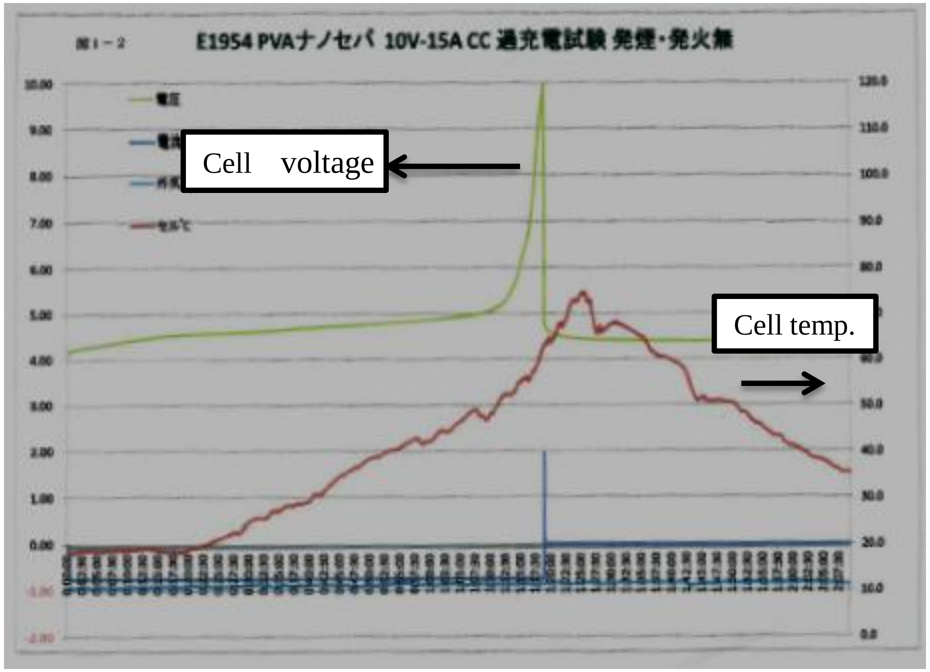
PVA/SiO_2 nanofiber

Wet-laid nonwoven (polyolefin)

Application Trial for LIB Separator-Over Charge Test

Overcharging test started form fully charged (4.15V) condition
Charging current：15A(0.5C) constant current
Upper limit charging voltage：10V

PVA nanofiber separator →Ignited by thermal runaway after overcharging of battery

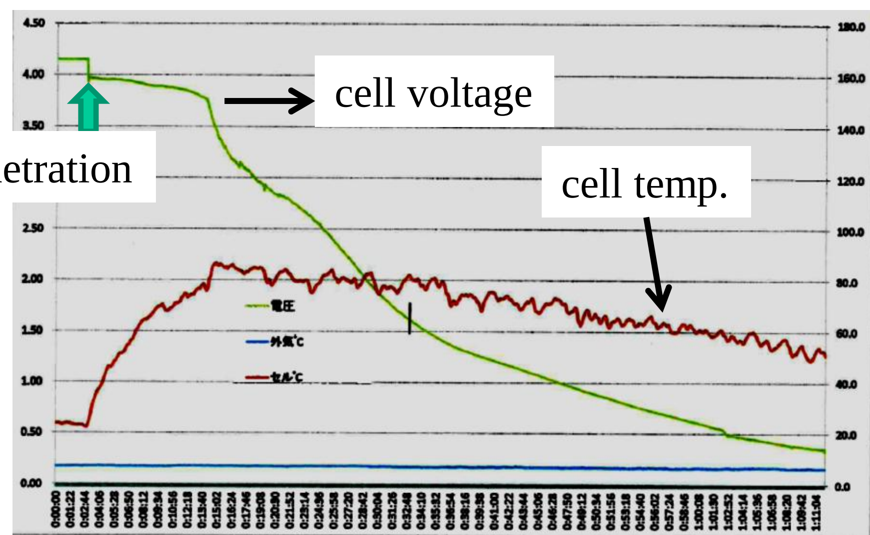


PVA /silica containing nanofiber separator→
No runaway happened during overcharging

Nail penetration test started form fully charged (4.15V) condition.
A 5mm SUS nail was struck into battery perpendicularly to laminated electrode

Nominal capacity
： 30 Ah

Thermal runaway does not occur on the battery with PVA /silica containing nanofiber separator



Potential Applications of HIROSE nanofibers

Applications	Technical Background
High performance/high safety Li-Ion Battery Separator	Ultrathin wet-laid nonwovens Polymer/Ceramic composite nanofiber
High Performance Filter Media (Air, Liquid)	Nanofiber diameter control technology
Apparel, Tissue Engineering, etc.	High throughput spinning technology (low cost)

Thank you for your attention

Contact information

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