Ultra-Thin Nonwovens for Industrial Applications

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Hirose Paper Mfg. Co., Ltd.

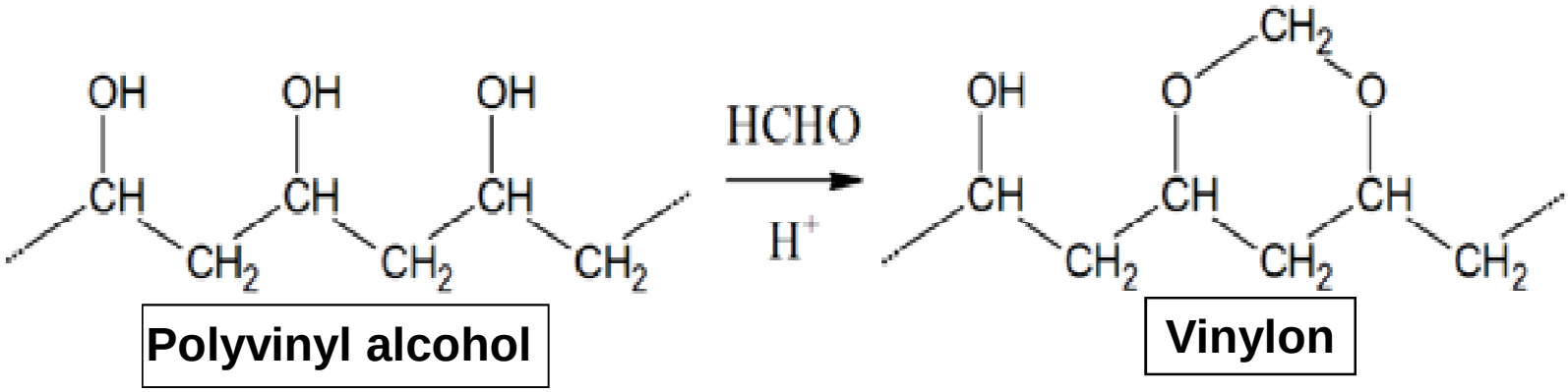
HIROSE High Performance Nonwovens

Presentation Outline

- History of wet-laid nonwoven developed in Japan
- Ultra-thin nonwovens for industrial applications
- Nanofiber-overlaid nonwoven
- Conclusions

History of Wet-Laid Nonwoven Developed in Japan

*It started from the invention of **Vinylon**…*



Polyvinyl alcohol

Vinylon

Vinylon : Synthetic fiber spun from PVA

- ***Crystallized by heat treatment***
- ***Crosslinked by formaldehyde***

Birth of Vinylon Paper

1935 **Nylon** was invented by Carothers at DuPont

1939 **Vinylon** **was invented by *Sakurada* et al. at Kyoto University**

1950 Commercial production of **Vinylon fiber** started

1952 ***Inagaki*** started development of **Vinylon paper** at Kyoto University

Birth of Vinylon Paper (cont.)

Problems of papermaking using synthetic fibers

1. No self-bonding

- Hydrophobic fiber surface
  >> poor H-bond formation

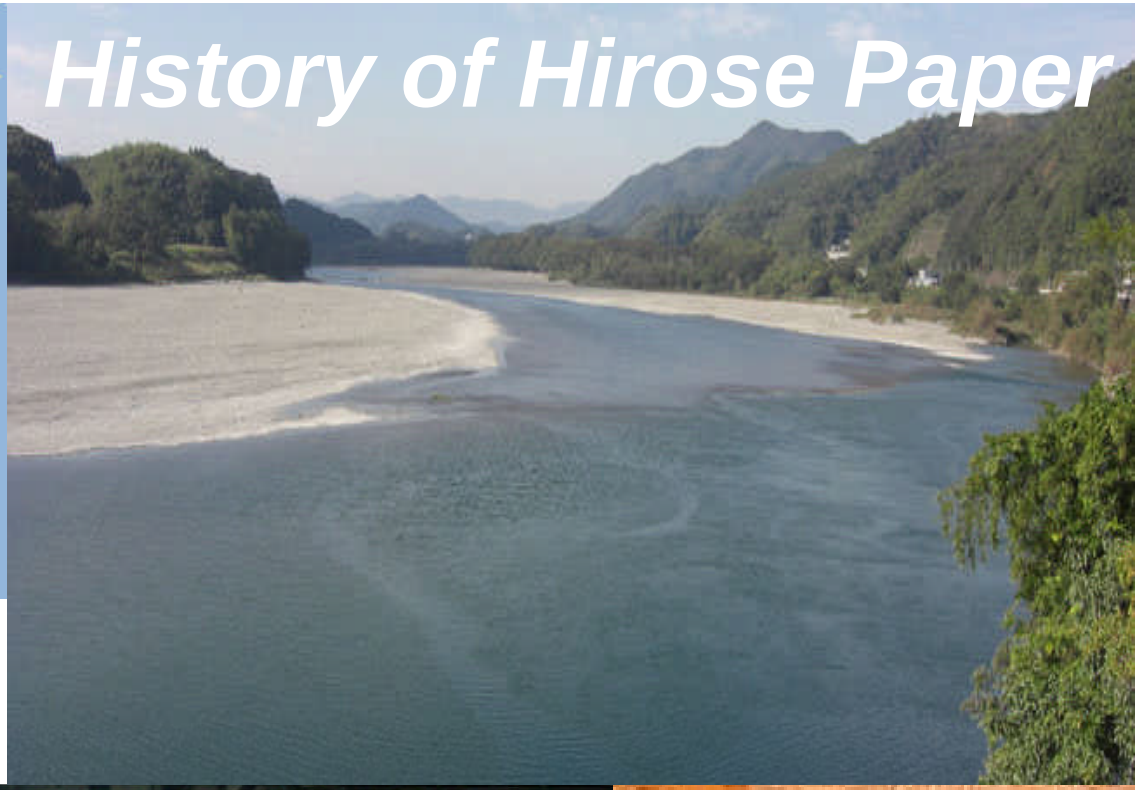
2. Poor formation

- Longer fibers (>5mm) cause strong entanglement
- Fast settling velocity causes poor dispersion

Prof. Inagaki

History of Hirose Paper

Paper making started in 920's



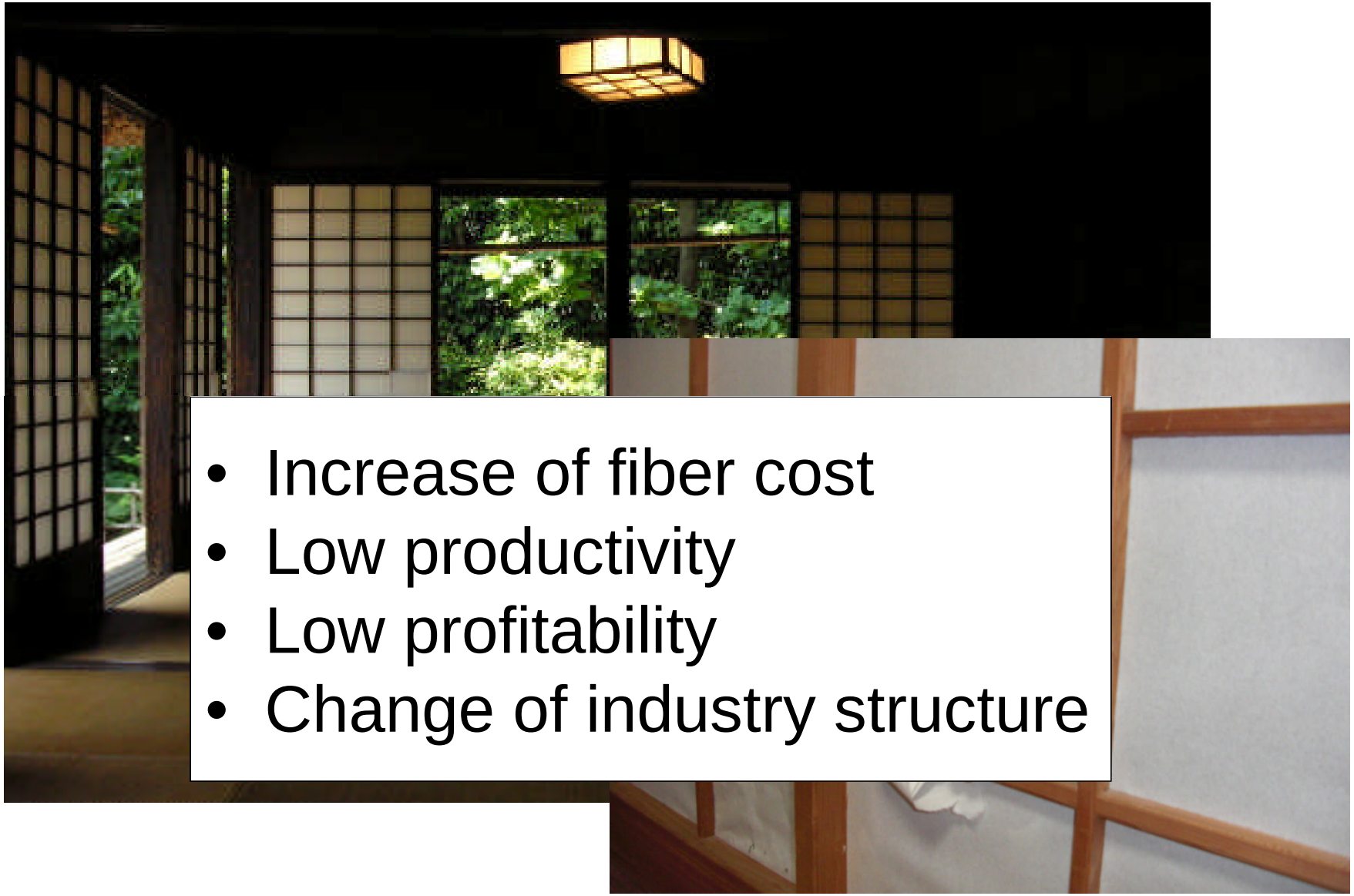
Shinji Hirose

Hirose Paper's factory

Traditional Tosa Paper

3.5 gsm

Shoji Screen Paper



- Increase of fiber cost
- Low productivity
- Low profitability
- Change of industry structure

Inagaki

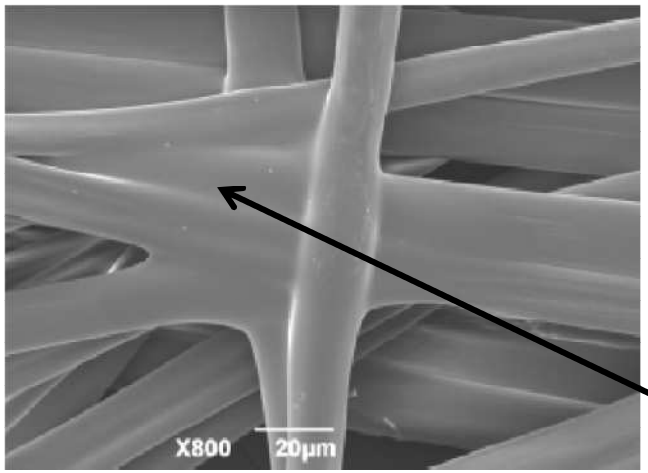
Hirose

1954 Hirose started research under ***Inagaki at Kyoto Univ.***

Birth of Vinylon Paper (cont.)

1. Solution for poor bonding → Binder fiber

- **Invention of PVA BINDER FIBER** for thermal bonding of synthetic fiber (Japanese patent,1957: Okamura and Inagaki)
- PVA binder fiber is produced by weak heat treatment of spun PVA fiber
- PVA Binder Fiber **melts on the surface at high moisture and high temperature** conditions on the dryer to generate binder effect



PVA Binder Fiber idea evolved to Polyolefin SHEATH-CORE FIBER invented by Chisso Corp.

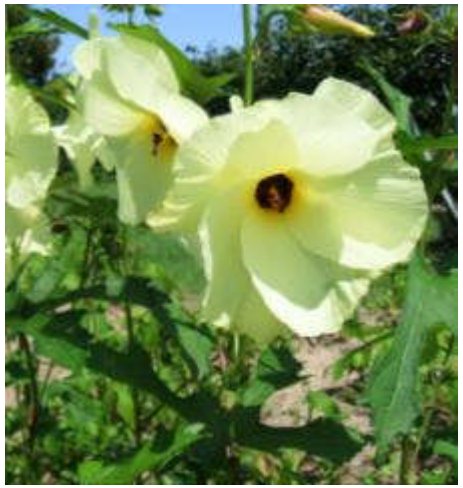
Bonding by melted PVA binder fibers

Birth of Vinylon Paper (cont.)

2. Solution for poor formation

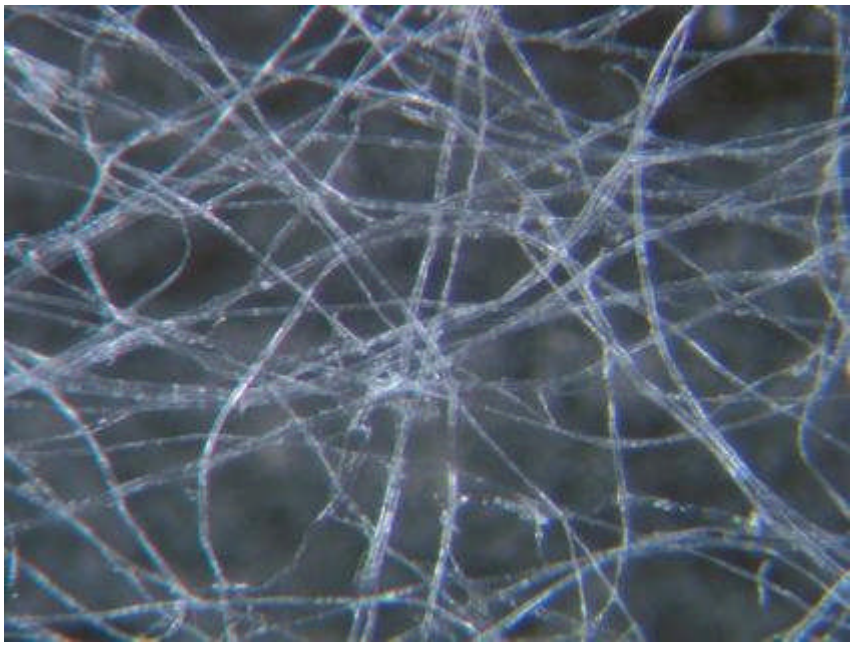
- Use of "**NERI**" (mucilage obtained from Hibiscus plant) as formation aid to prevent flocculation of long fibers
  (Application of traditional Japanese papermaking method)

  NERI= Polyuronic Acids
- Usage of synthetic NERI = **"Polyethylene oxide"**



Hibiscus plant

Neri



Dispersed long bast fiber using Neri

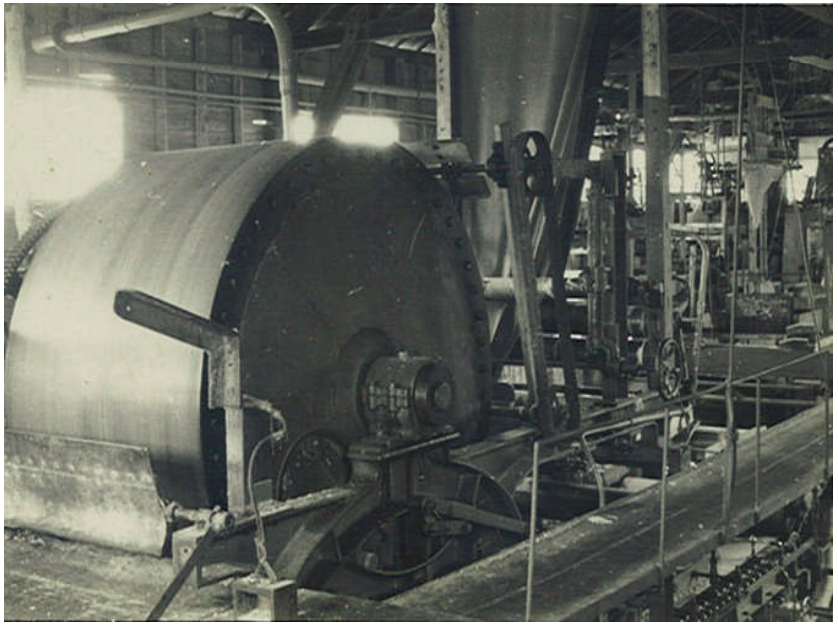
Birth of Vinylon Paper (cont.)

1954 ***Hirose*** started research under ***Inagaki***

1957 **Vinylon paper was invented by Okamura, Inagaki and Hirose**

1958 **Hirose Paper** stated production of **Vinylon paper**

Tokushu Paper stated production of **Nylon paper**



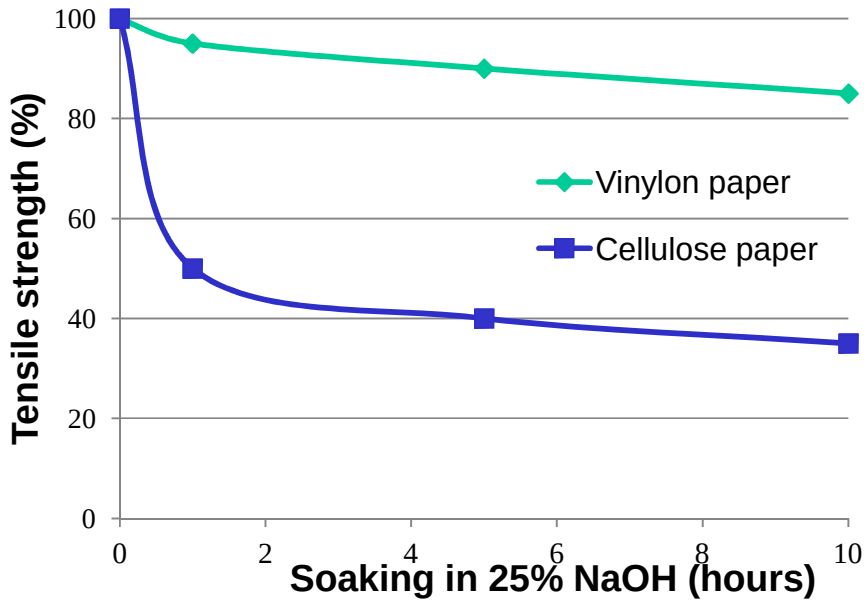
Dryer of Hirose Factory

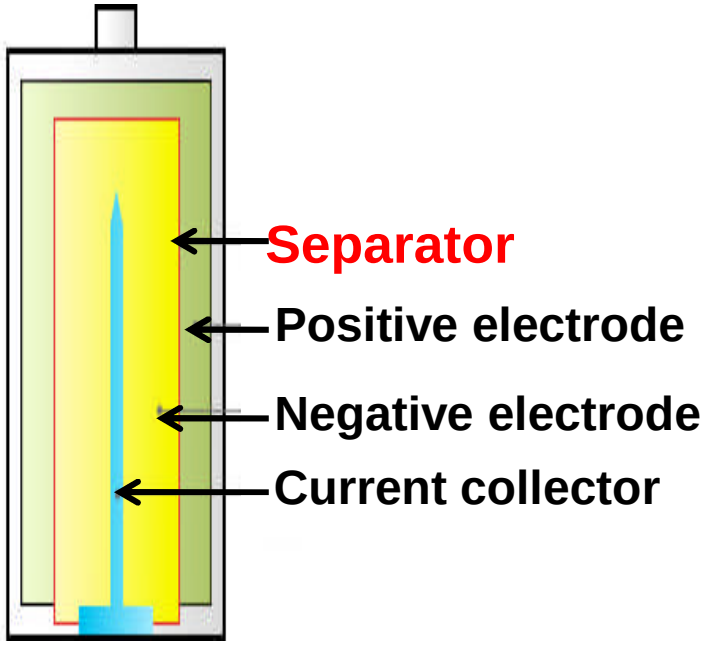
First application of Vinylon paper => Shoji screen paper

Industrial Application of Vinylon Paper

Alkaline-Manganese Battery Separator

- ❑ **Excellent alkali resistance**
- ❑ Excellent wetability
- ❑ Excellent electrolyte absorbability
- ❑ High strength
- ❑ High heat resistance

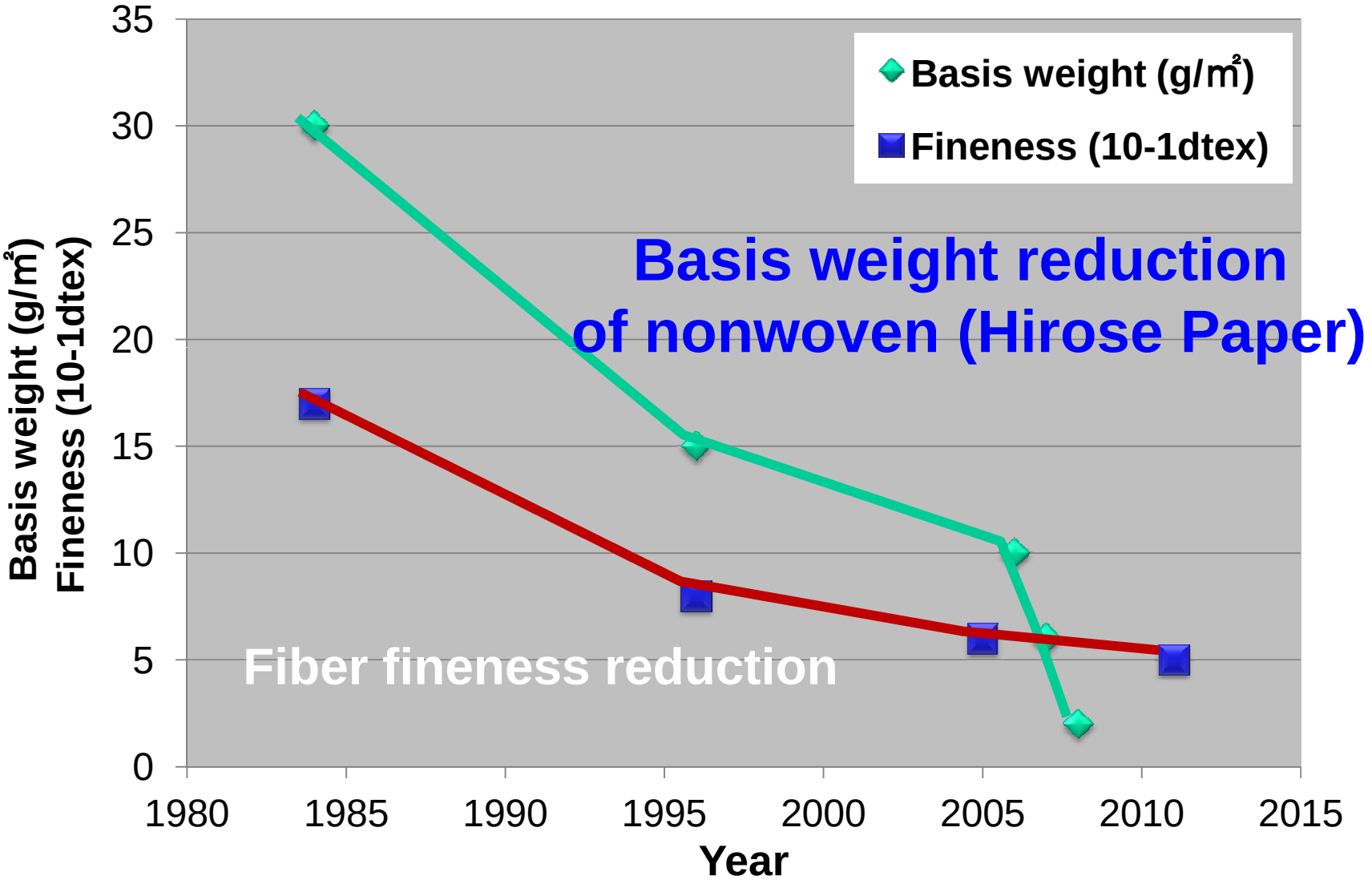




Ultra-thin Nonwovens for Industrial Applications

Thinnest nonwoven in the world
2g/m^2 polyolefin nonwoven manufactured by Hirose Paper

Pursuance of Thinnest Nonwoven in the World by Hirose Paper

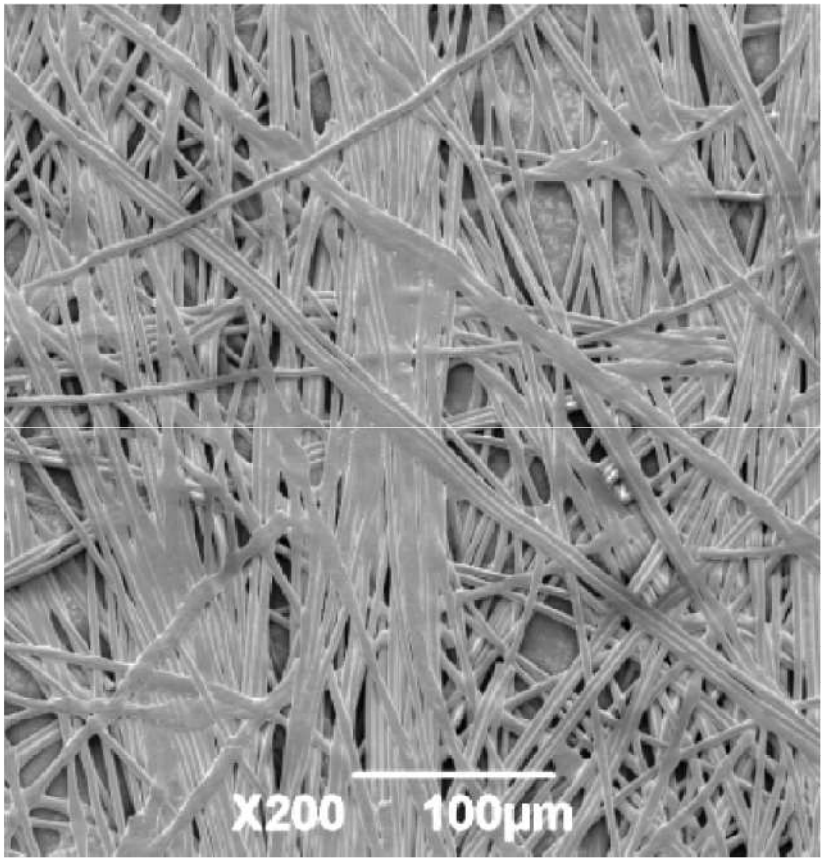


What is Ultra-thin Nonwovens?

2 GSM polyolefin nonwoven (Hirose Paper)

- Wet-laid nonwoven lighter than 15 GSM with good formation is hard to manufacture
- Basis weight reduction is getting important for high-tech applications
- **Lowest basis weight** achieved:
  - Polyester nonwoven > 5GSM
  - Polyolefin nonwoven > 2GSM
  - Vinylon nonwoven > 8 GSM

Properties of Polyester Nonwoven

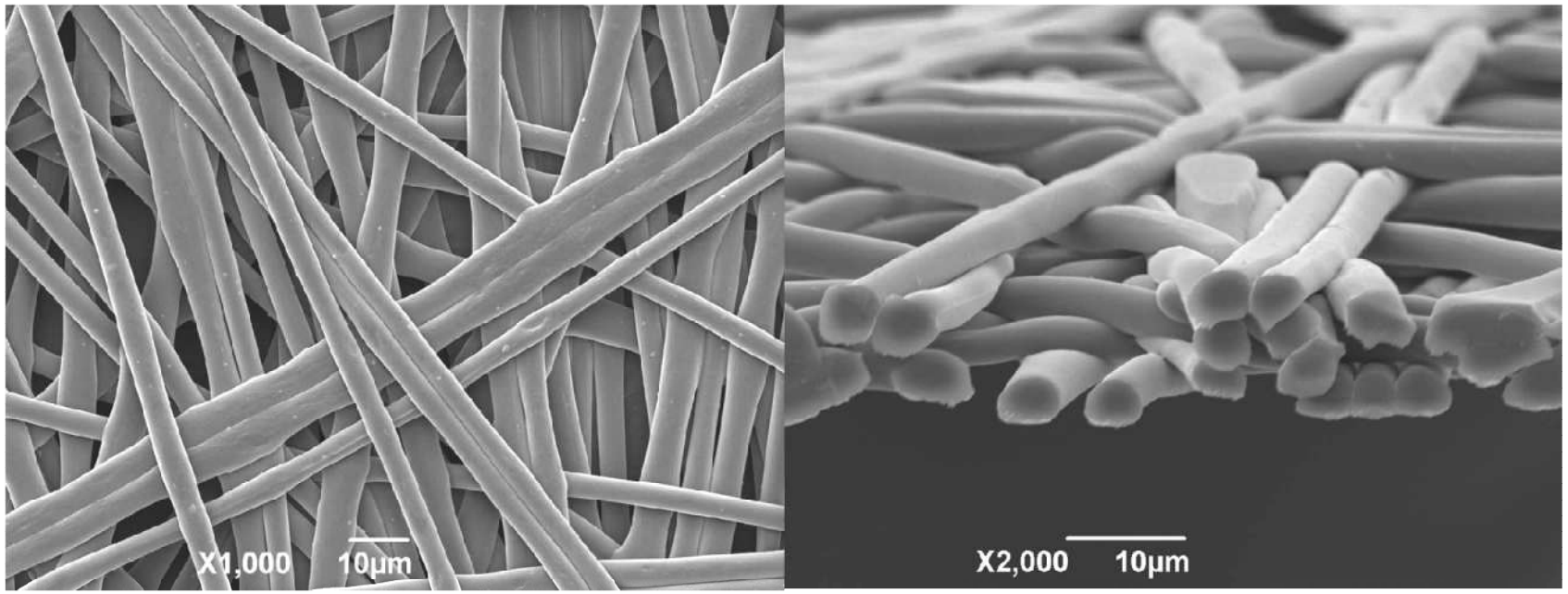


- High strength (dry and wet)
- High dimensional stability
- High heat resistance
- High chemical resistance
- High weather resistance
- High electrical insulation
- Low cost

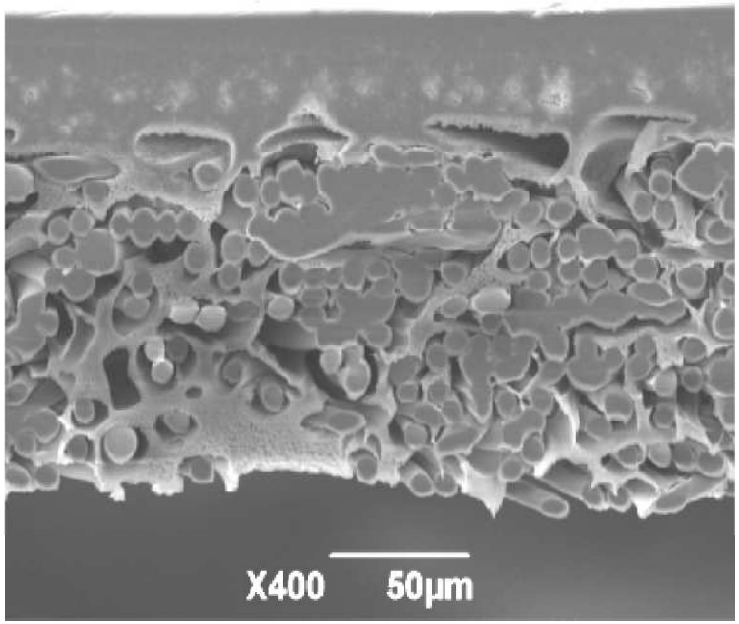
Li-ion Battery Separator

- High performance Li-ion battery separator: **thin polyester nonwoven with silica coating**

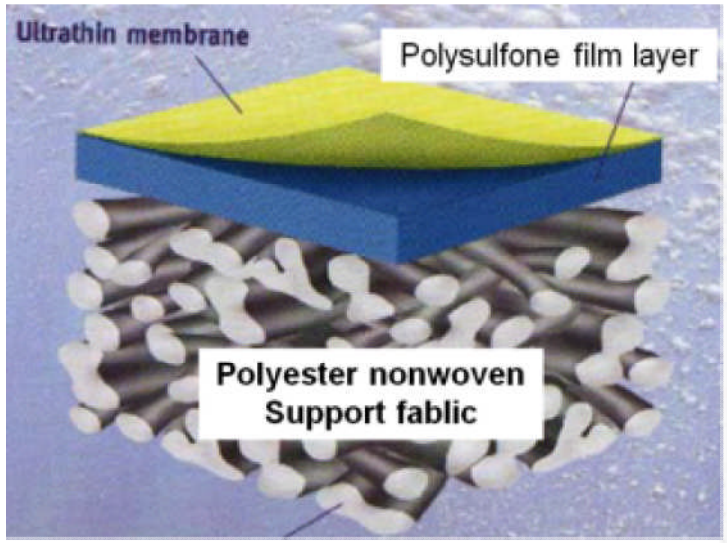
- **Silica coating enhanced heat resistance and prevents thermal runaway**

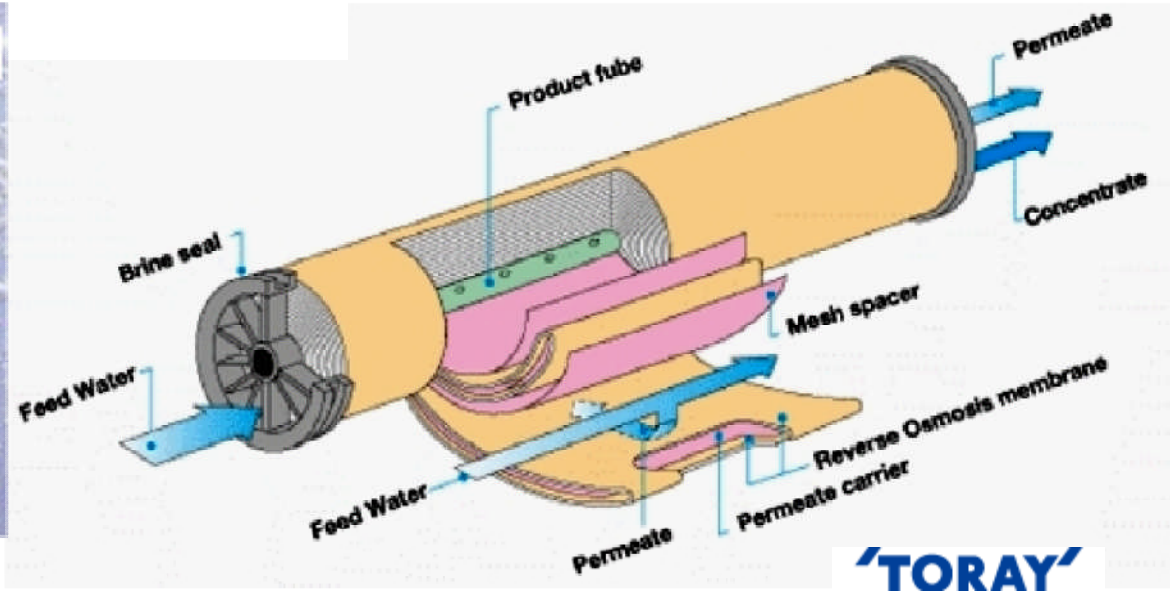


Reverse Osmosis Membrane



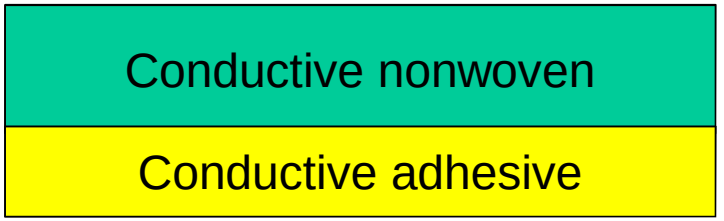
- Desalination of seawater
- Uniform and high strength polyester nonwoven
- Suitable for the bucking layer of R/O membrane





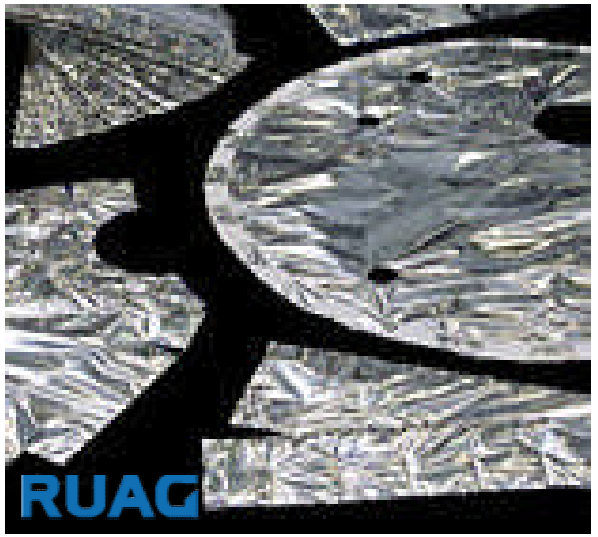
Electromagnetic Noise Suppression Sheet

- Ultra-thin polyester nonwoven with metal-plating
- Prevent or diminish electromagnetic interference in electric apparatus
- With conductive adhesive layer for easy attachment to the devices
- Thin, light and flexible



Superinsulation

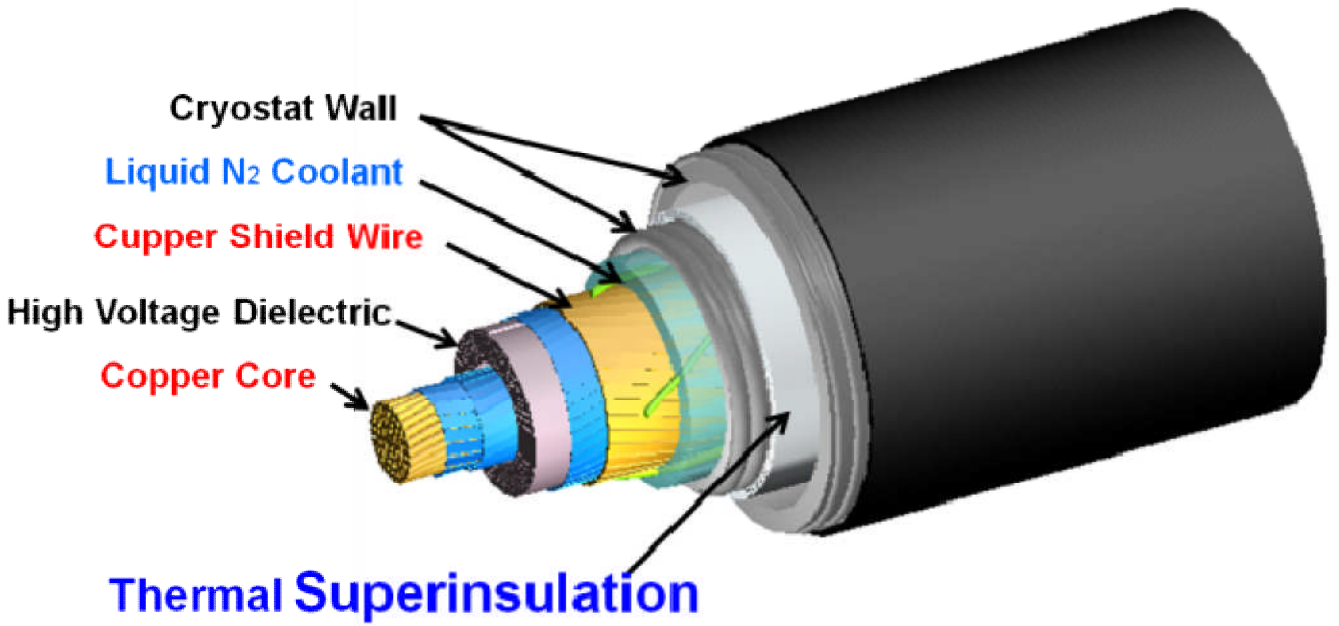
- Insulated vacuum jackets are made of thin polyester nonwoven and aluminum foil
- Nonwoven works as spacer separating foils
- Nonwoven minimizes heat conductance



Superinsulation

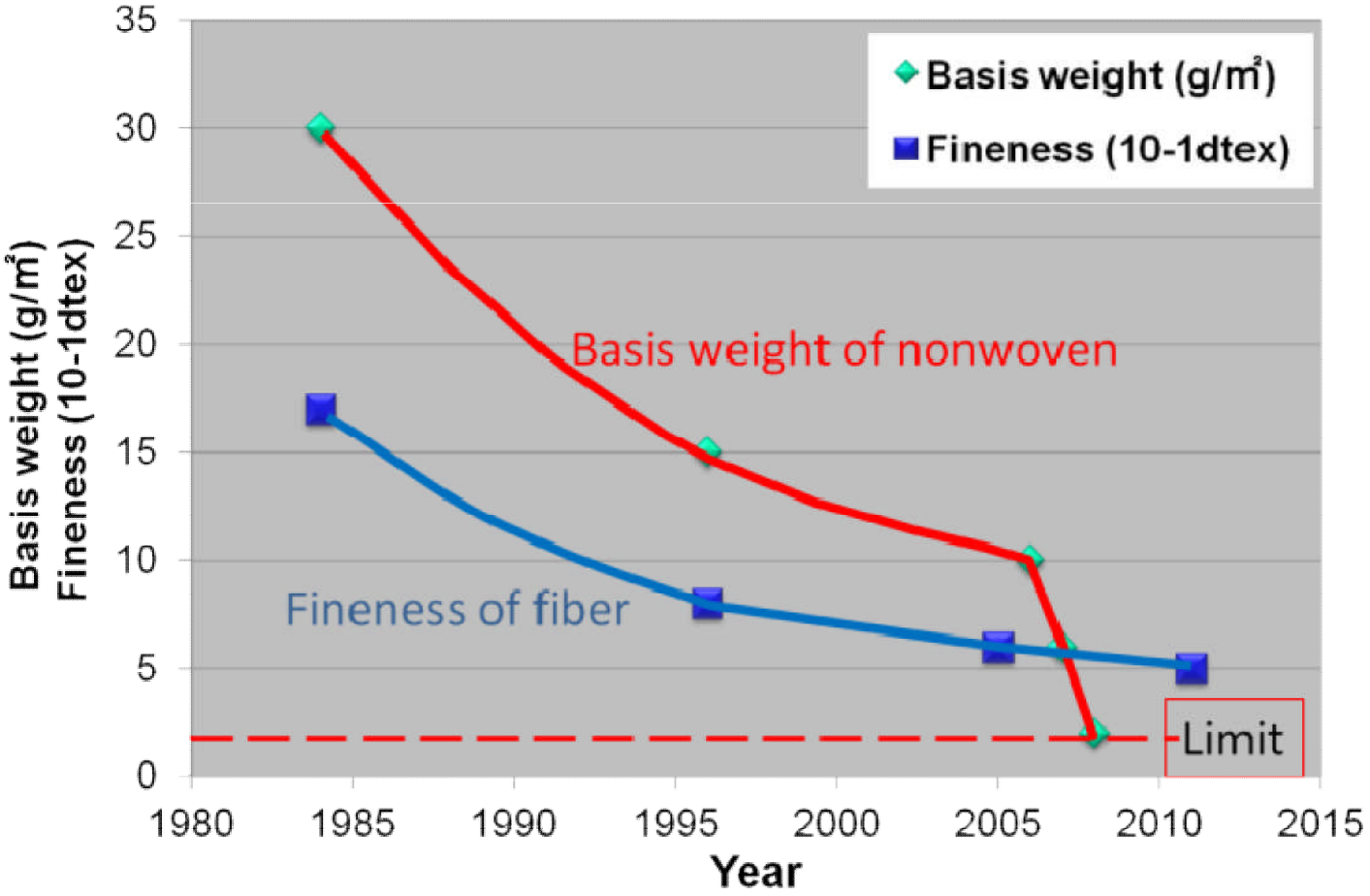
Superconducting Power Cable

- Ultra-thin polyester nonwoven is suitable for Thermal Superinsulation Layer of the high-temperature superconductor (HTS) cable
- HTS cables can carry three to five times the power of conventional copper cables



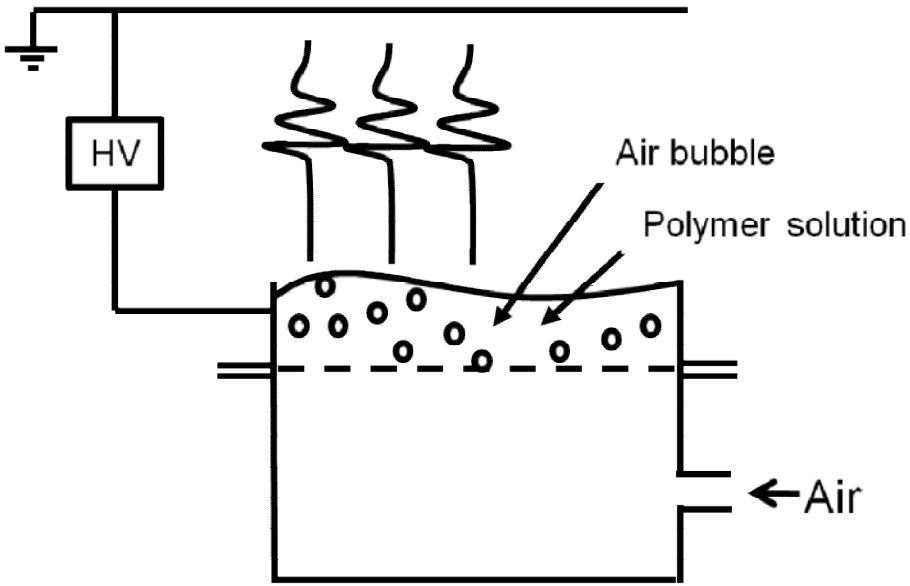
Nanofiber-Overlaid Nonwoven

Beyond the bounds of ultra-thin nonwoven



Nanofiber Overlaid nonwoven
Hirose Paper's Electro Bubble Spinning

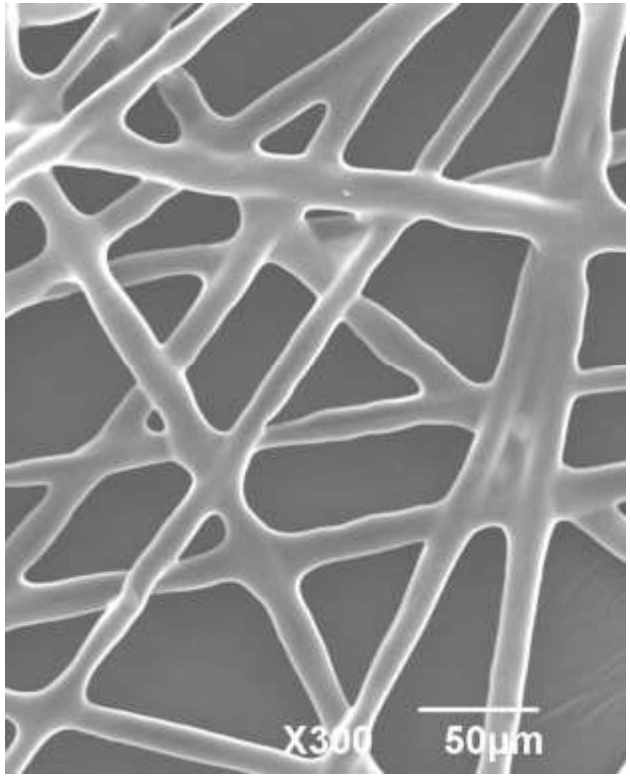
Nanofiber production by nozzle-free electrospinning (Patented)



- ❑ Simple system
- ❑ Low capital cost
- ❑ Low maintenance
- ❑ **Low production cost**

Nanofiber Overlaid Nonwoven

Ultra-thin Nonwoven



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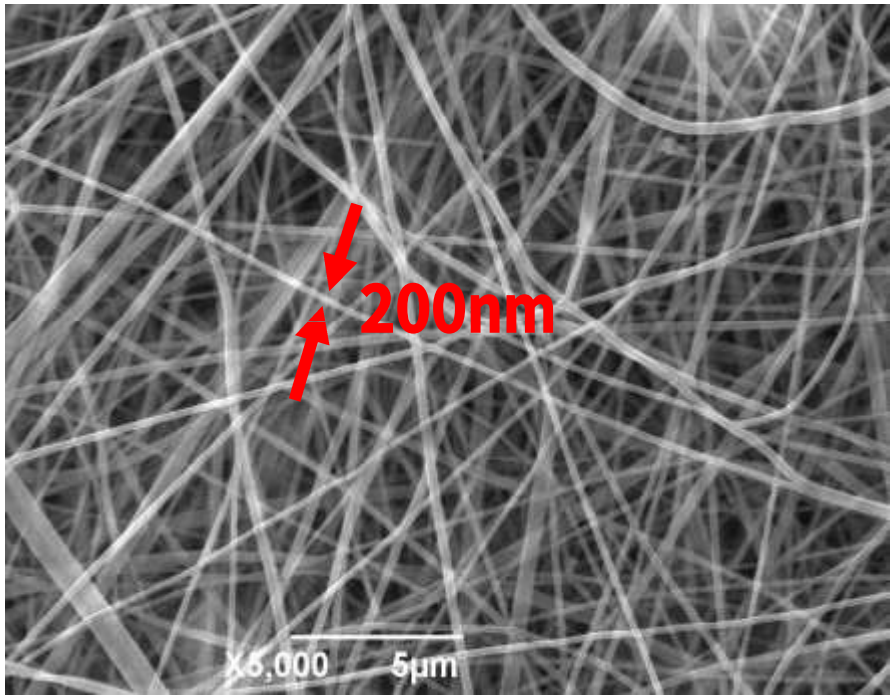
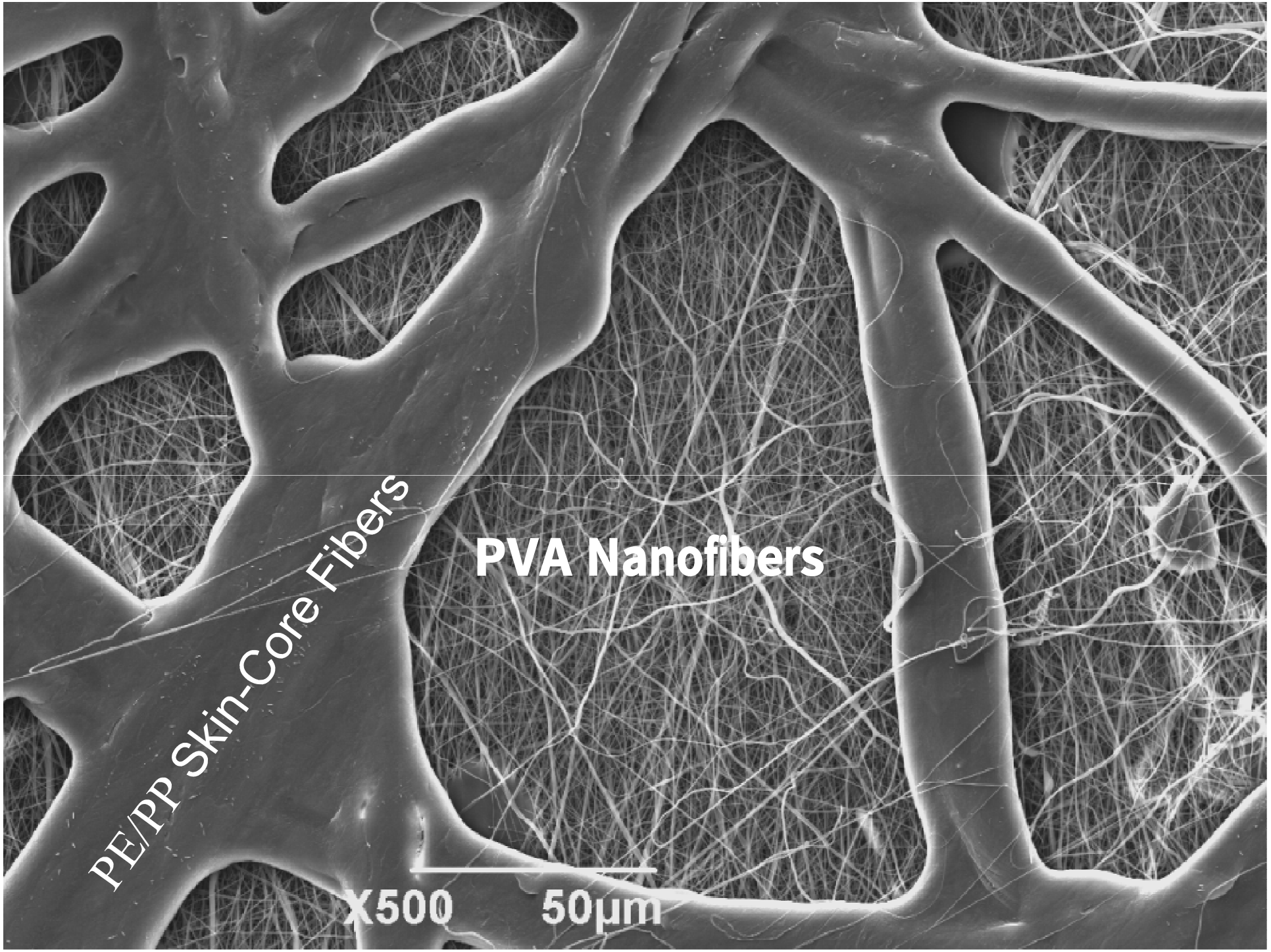
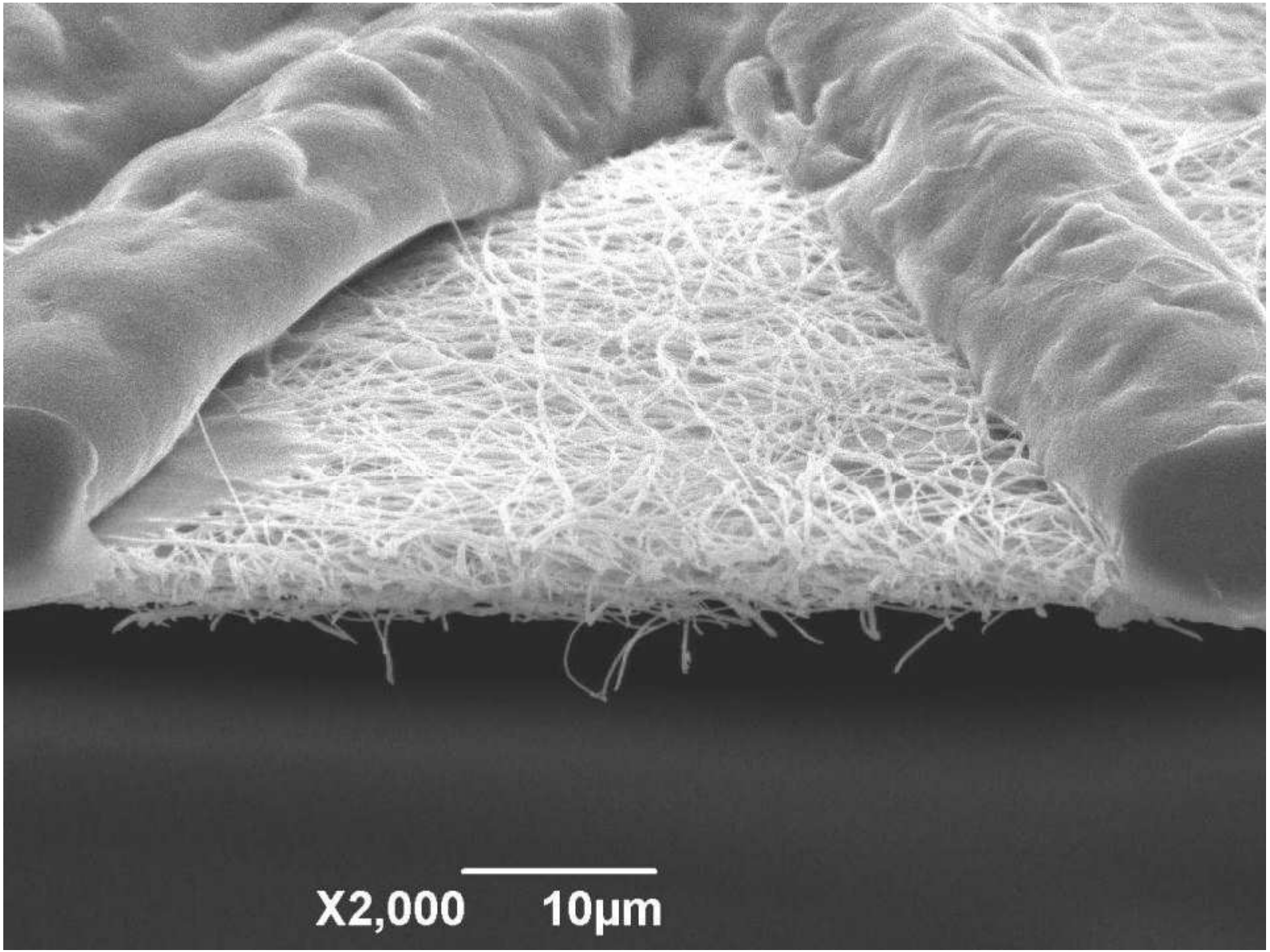
Nanofiber



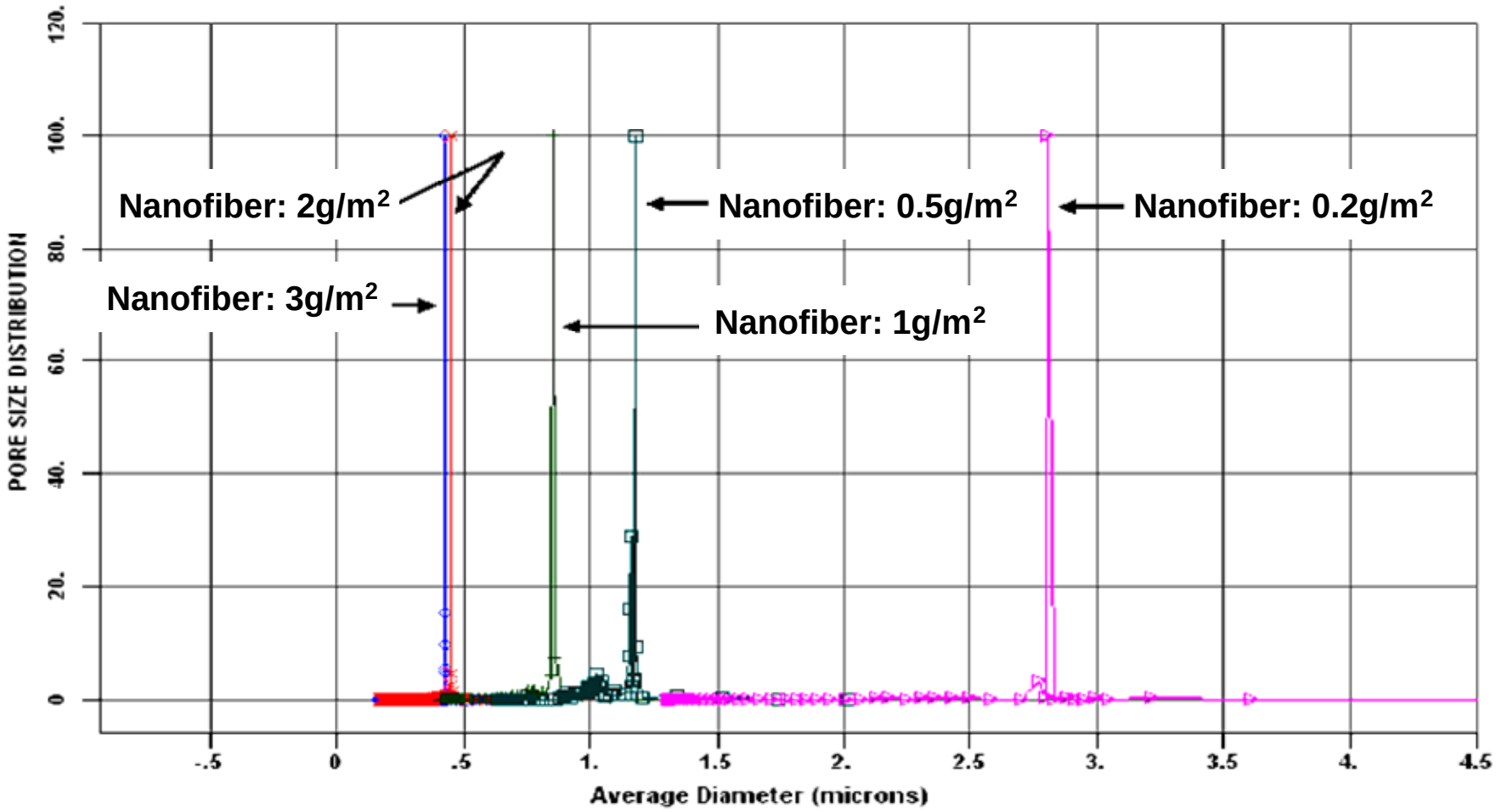

PE/PP Skin-Core Fibers
PVA Nanofibers
X500
50μm


X2,000
10µm

Nanofiber Overlaid Nonwoven

Pore size reduction by nanofiber layer

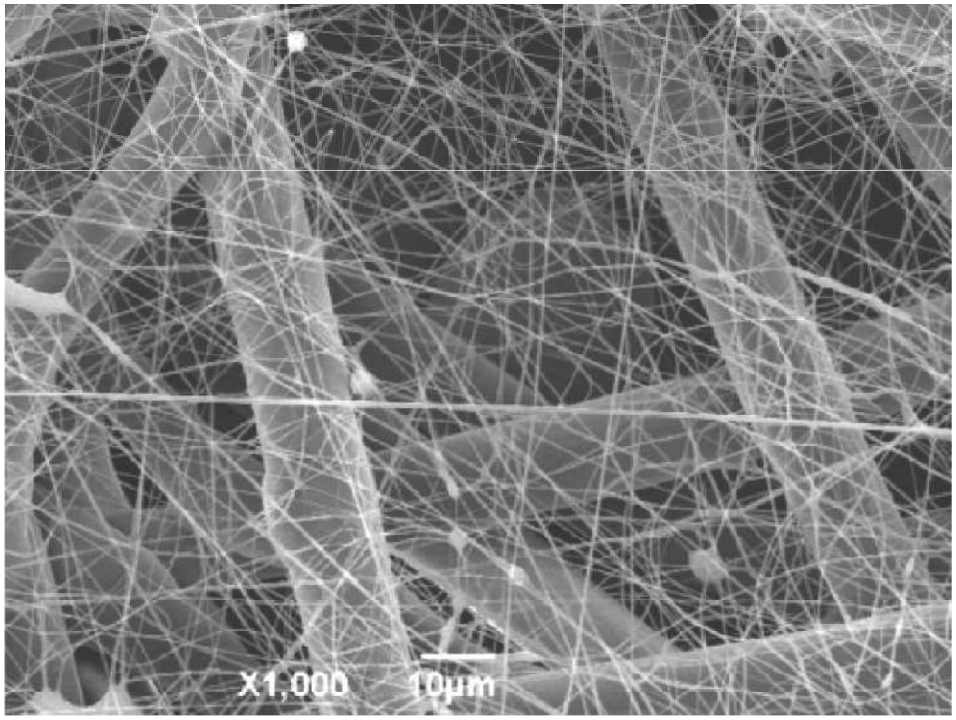
Small amount of overlaid nanofiber reduces pore size significantly



Applications

Li-ion Battery Separator

Air Filter



Conclusions

- Demand for low basis weight nonwovens with excellent uniformity is getting higher due to the increase of high-value-added "light and compact" products
- Ultra-thin wetlaid nonwoven is opening up new high tech applications
- Composites of thin nonwovens and nanofiber offer properties which cannot be achieved by nonwovens

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Type	Basis Weight	Thickness	Tensile Strength N/15mm		Air Permeability
	g/㎡	μm	MD	CD	cc/cm^2・sec
06HOP-2	2.08	16	0.9	0.4	398<
05TH-5	4.95	30	1.7	0.5	398<
VH-1008	7.96	39	6.6	2.6	156