Industrial Scale Production of Nanofiber Overlaid Nonwoven

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1. Introduction

Electrospinning technology of nanofibers can be categorized into two methods: 1) conventional nozzle-based method, and 2) nozzle-free method. Nozzle-based electrospinning has a long history and nanofiber webs have been produced by this method. Elmarco, a Czech-based company, has developed a nanofiber production machine using a nozzle-free electrospinning method. Their system is based on free liquid surface electrospinning of nanofibers from a rotating drum surface.

We have developed a new nanofiber production system by nozzle-free electrospinning method that is not drum-based. The major advantage of our system is low capital cost because our method is simpler. Thus, low cost production of nanofibers for battery separator and high performance filter applications is now possible.

Fig. 1 PVA polymer jet generated from spinning unit (nozzle free)

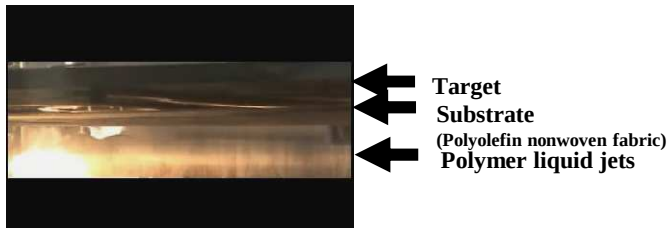

Fig. 2 Pilot production line

Various manufacturing parameters have been tested on this line.

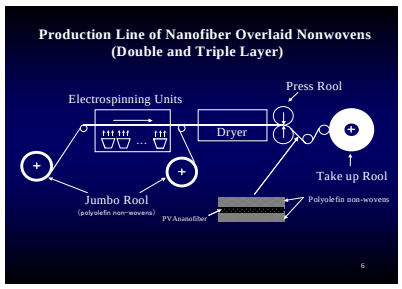

Fig. 3 Production process of PVA nanofiber overlaid nonwoven

Nanofiber is overlaid on the surface of polyolefin nonwoven for the improvement of handling property (two- layer structure). Additional layer of nonwoven can be added to the nanofiber side to make three-layered structure.

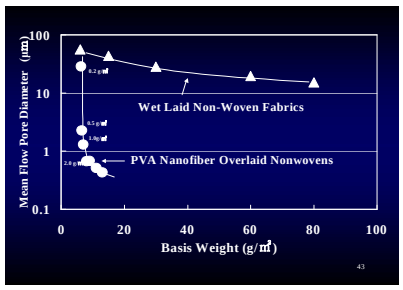

Fig.4 Effect of basis weight to the polyolefin nonwoven and nanofibe overlayed nonwoven (two-layered) on mean flow pore diameter

Mean pore diameter of polyolefin nonwoven made of macrofibers (16μm in diameter) cannot be reduced smaller than 10μm by the increase of basis weight. Significant reduction of mean flow pore diameter to the submicron range can be achieved by overlaying small basis weight of

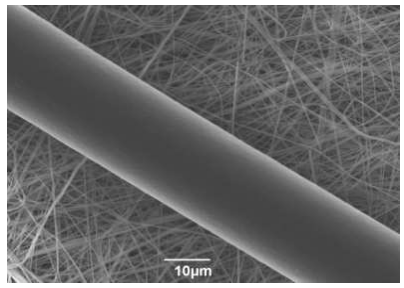

Fig. 5 SEM micrograph showing diameter difference of typical polyolefin fiber for wetlaied nonwoven (about 16 μm) and electrospun PVA nanofibers (about 200 nm)

Nanofiber overlaid nonwoven consists of these two different fibers of totally different sizes.

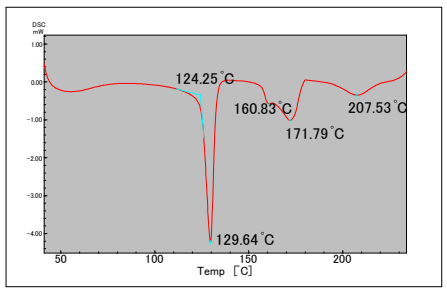

Fig. 6 DSC curve of nanofiber overlaid nonwoven consisted of PVA nanofiber and PE/PP sheath-core fiber

The curve shows heat adsorption peaks of PVA, PE and PP at 207.5 °C, 129.6 °C, and 171.7 °C, respectively.

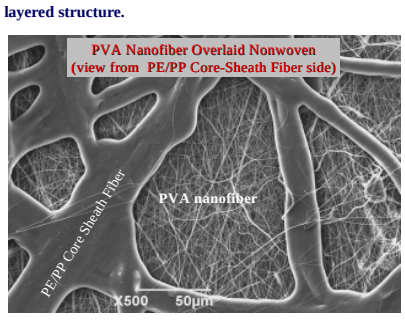

Fig. 7 SEM micrograph of nanofiber overlaid nonwoven (nonwoven layer side)

Large pores of wetlaid nonwoven is covered by nanofibers to achieve significant pore size reduction

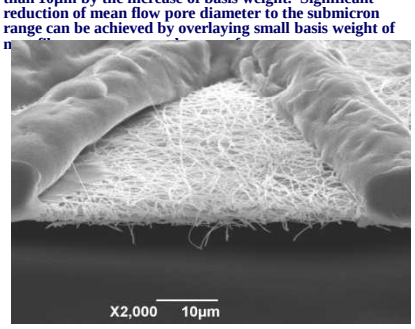

Fig. 8 SEM micrograph of nanofiber overlaid nonwoven (cross section)

Melted PE of PE/PP core sheath fiber penetrated into nanofiber web to form strong bonding. No damage is seen on the nanofiber web caused by the press roll

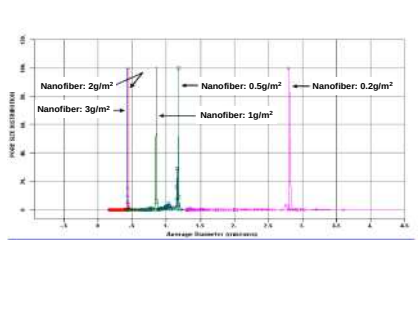

Fig. 9 Pore size destribution of nanofiber overlaid nonwoven

See extreme narrow pore size distribution

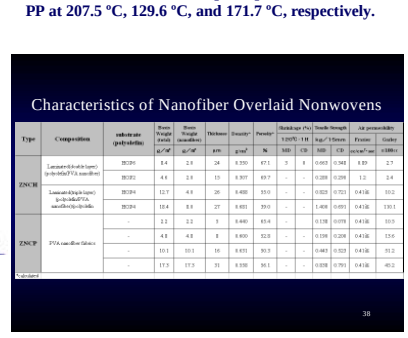

Table 1. Physical properties of nanofiber products including nanofiber overlaid nonwovens (two and three-layered products) and nanofiber web by itself

All of these products are available for sale and evaluation.

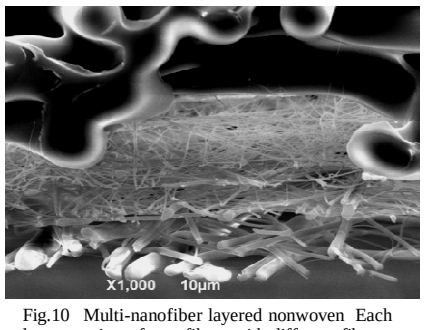

Fig.10 Multi-nanofiber layered nonwoven Each layer consists of nanofibers with different fiber diameter.

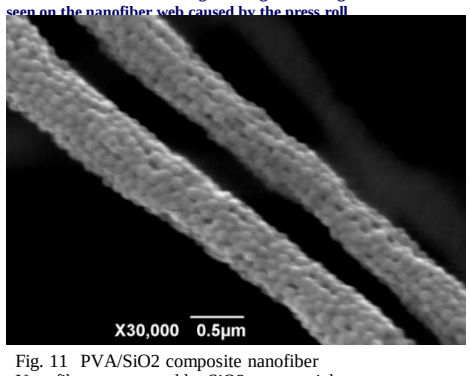

Fig. 11 PVA/SiO2 composite nanofiber Nanofibers are coated by SiO2 nanoparticles (100nm) on the surface. Significant improvement of heat resistance can be achieved

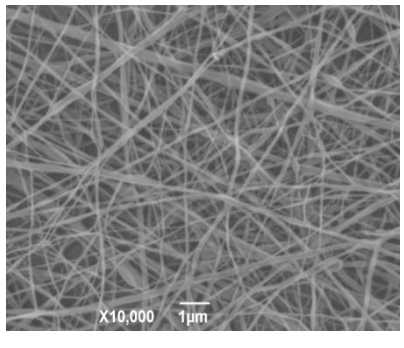

Fig. 12 . Organic solvent based PVDF nanofiber

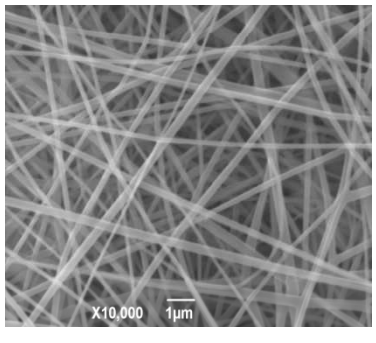

Fig. 13 Organic solvent based PAN nanofiber

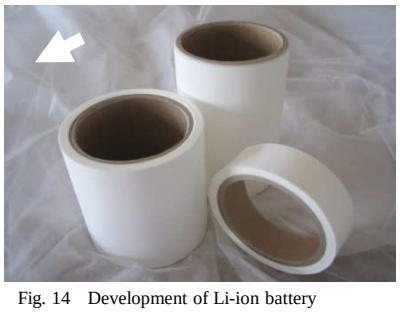

Fig. 14 Development of Li-ion battery separators

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Fig. 15 Production line of nanofiber overlaid nonwoven

Conclusions

1. Hirose Paper has established industrial scale production of nanofibers by nozzle-free electrospinning technology.
2. This innovative technology was combined with ultra-thin wetleid nonwoven manufacturing technology of Hirose Paper and “Nanofiber Oerlaid Nonwovens” was born.
3. Combined layered structure of ultra-thin wetlaid nonwoven and nanofibers improved handling of nanofibers significantly without hindering superior properties of nanofibers.
4. New development:
   - Nanofiber /SiO2 composite
   - Multi-layered nanofiber nonwoven
   - Organic solvent based nanofiber (PAN, PVDF, PI)
5. Production line has been completed