

Development of Nano Ceramic Structures for HEPA Type Breathing Wall

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ABSTRACT: In the perspective of saving energy in buildings, high performance of insulation and air tightness for improving the heating and the cooling efficiency has brought the positive effect in an economical view. However, these building energy saving technologies cause the lack of ventilation, which is the direct cause of increasing the indoor contaminants, and it is also very harmful to residents because they spend over 90% of their time in the indoor area. Therefore, the ventilation is important to keep indoor environment clean and it can also save energy consumption. In this study, a HEPA type breathing wall is designed as a passive ventilation system to collect airborne particles and to supply fresh outdoor air. To make fine porous structures, polymer nano fibers which were made by electrospinning method are used as a precursor. The nano fibers are coated with SiO₂ nano particles and finally the HEPA type breathing wall is made by sintering in the electric furnace at 300~500°C. The pressure drops of nano ceramic structure are 8.2, 25.5 and 44.9 mmAq at the face velocity of 2.0, 5.9 and 8.8 cm/s, respectively. Also the water vapor permeability is 3.6 g/m²·h·mmHg. In this research, the porous nano ceramic structures are obtained and the possibility for the usage of a material for HEPA type breathing wall can be obtained.

Keywords: Breathing wall, ventilation, pressure drop, porous nano ceramic structure, electrospinning

1. INTRODUCTION

Recent high insulation and air tightness of buildings for the prevention of energy loss cause lack of ventilation and degrade the indoor air quality. Therefore the mechanical and/or natural ventilation systems are considered to improve indoor air quality. As an active method, the mechanical ventilation system with total heat exchanger is widely used especially in the high-rise apartments. But the mechanical

ventilation system consumes additional electric power, and has some restricts such as ventilation rate and efficiency when it is compared to the past living custom.

On the contrary, in Japan and England, the research for the concept of breathing wall as a passive ventilation system has been investigated. In Japan, the breathing wall was fabricated using porous aluminium seat, and evaluated some key factors, which affects the breathing performances, such as the heat transfer capacity, humidity

penetration efficiency, and ventilation efficiency. The England type breathing wall was composed of a fireproofing glass fiber mat which can collect airborne particles effectively and a frame of styrene foam. They measured some characteristics such as dynamic insulation, ventilation rate, and dust collection. Especially the module of breathing wall named “Energyflo” is commercialized in England.

Thus, in this research, the HEPA filter type breathing wall, which will be a component of the breathing wall, is designed and evaluated, and also analysed the possibility for the application of the breathing wall for the prevention of intrusion of airborne particles.

2. EXPERIMENTAL METHODS AND EQUIPMENTS

2.1 Process for the production of Nano ceramic structure

The HEPA filter is usually made of glass fibers with binders, and cellulos, and generally it has diameter of several μm . For the fabrication of breathing wall, which has the similar performance with HEPA filter, the fiber diameter is designed less than 1 μm and considered to be coated with ceramic materials such as SiO_2 , Al_2O_3 , and TiO_2 .

Figure 1 shows the process for the fabrication of porous nano ceramic module which will be a key component of breathing wall. The nano fiber filter, whose diameter is less than 500 nm, is produced by electrospinning using the PEO (Poly Ethylene Oxide) and coated with SiO_2 nano particles by dipping method. After removing the moisture in the coated material, it is sintered in the electric furnace until the polymer materials are removed. And finally the porous nano ceramic structures are produced.

2.2 Electrospinning

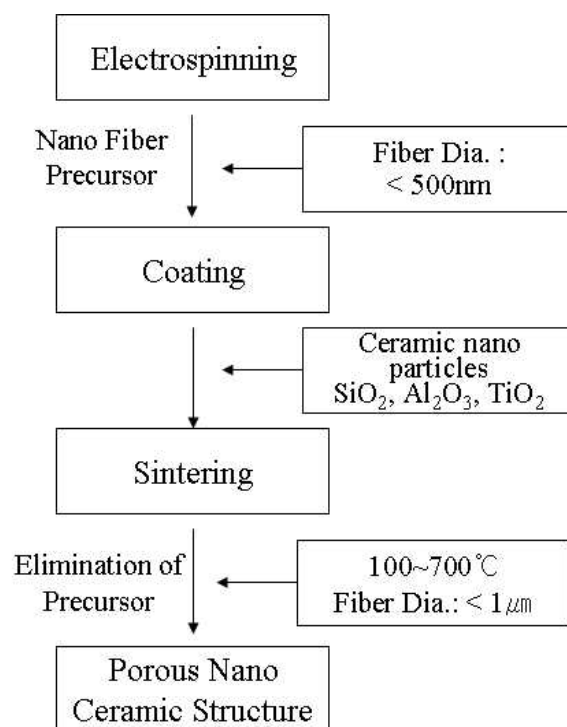


Figure 1: Process to make the HEPA type breathing wall.

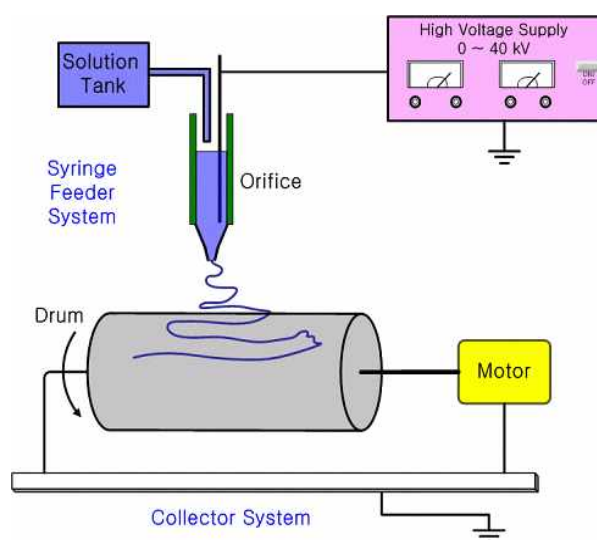


Figure 2: Schematic diagram of the electrospinning.

Figure 2 shows a schematic diagram of the electrospinning process. It consists of the syringe feeder system, the collector system, and the high voltage power supplier. High electric field strength is generated between a polymer fluid contained in a glass syringe and a metallic collector.

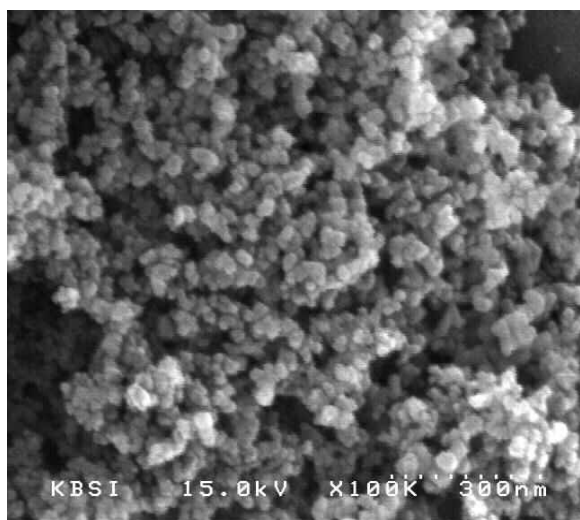


Figure 3: SiO₂ silica nano particles.

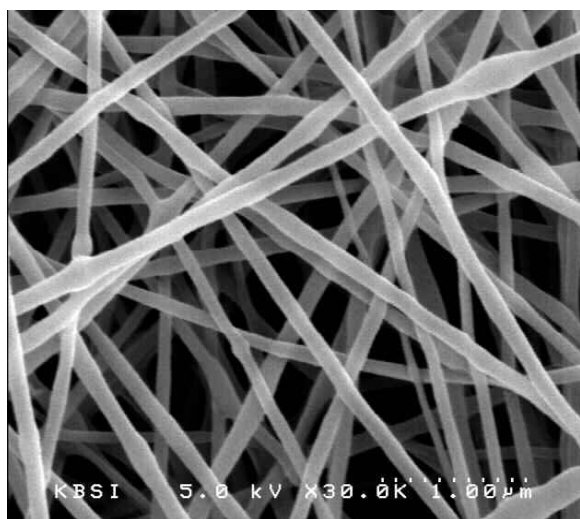
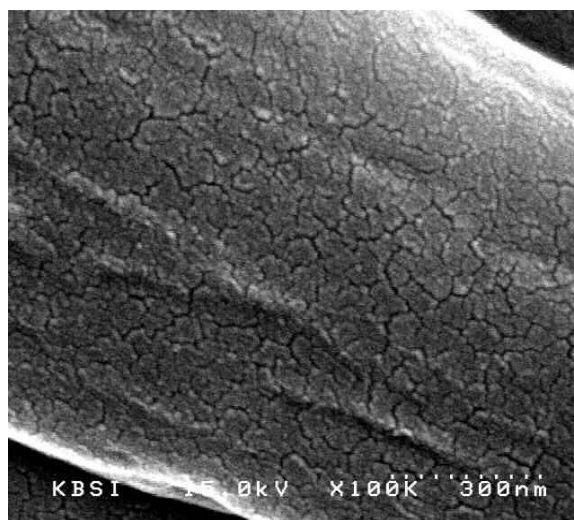
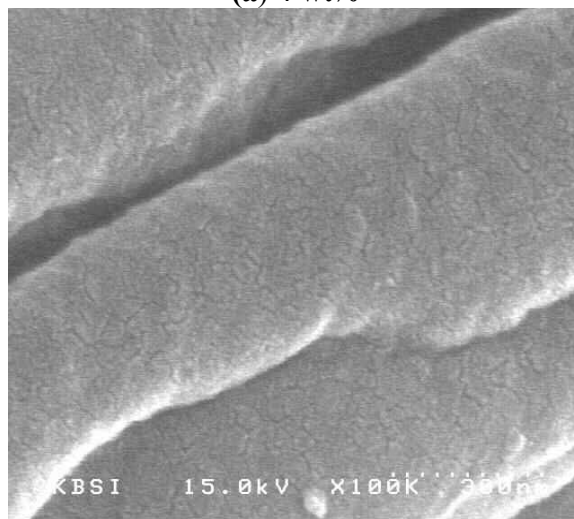


Figure 4: The Scanning electron micrograph of the electrospun fibers from a 10 wt% PEO solution dissolved in water (Electric field strength: 2kV/cm).

The hemispherical shape of pendant droplet at the end of syringe tip is changed into a conical shape with increasing voltage, which is known as the Taylor cone. When the voltage reaches a critical value, the electric force overcomes the surface tension of the deformed drop of the suspended polymer solution formed on the tip of the syringe, and a jet is produced. A jet travels through the air, the solvent evaporates leaving behind polymer fibers to be collected on an electrically grounded target.



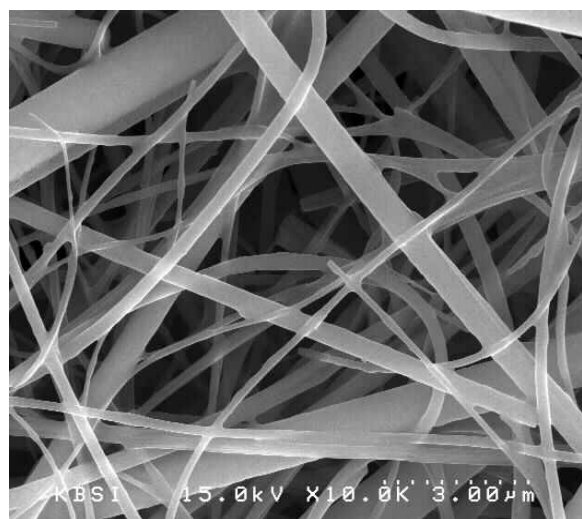
(a) 4 wt%



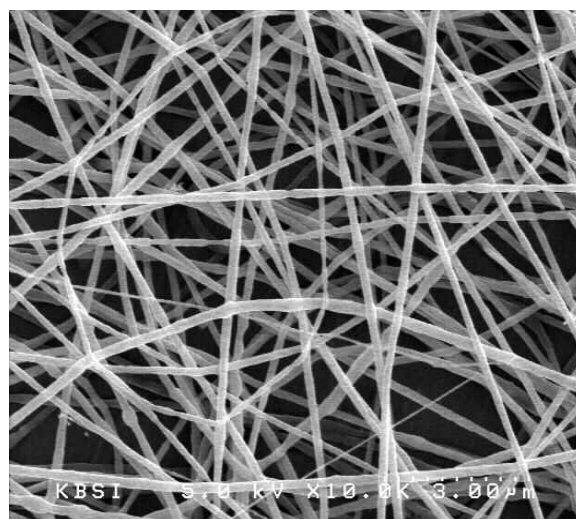
(b) 6 wt%

Figure 5: Coated surfaces of nano fibers with SiO₂ nano particles as a function of SiO₂ concentration.

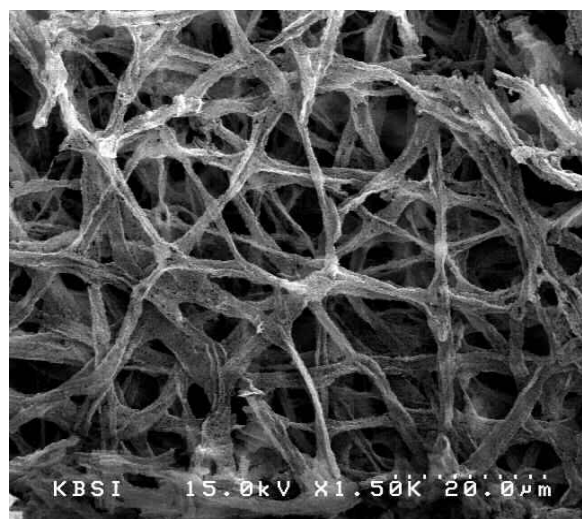
This means that the electrospinning jet can be thought of as string of charge elements connected by a viscoelastic medium, with one end fixed at the point of origin and the other end free. The free end of the electrospinning jet follows a chaotic path as it travels toward the grounded collector. This chaotic motion is the result of a complicated interaction of variables that involve viscosity, conductivity, surface tension, electrostatic force, air friction, gravity and ambient parameters.



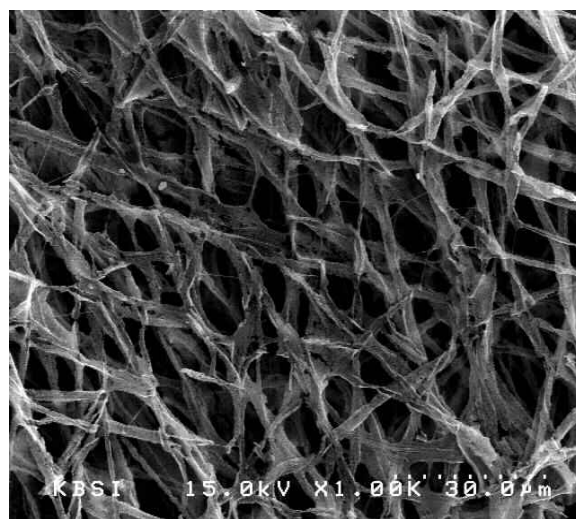
(a) HEPA filter



(b) PEO Nano fiber



(c) Nano ceramic structure fabricated at 300°C



(d) Nano ceramic structure fabricated at 500°C

Figure 6: Scanning electron micrographs of the HEPA filter, the PEO nano fiber, and the nano ceramic structures.

2.3 Producing the nano ceramic frame

The polymer nano fiber, which is produced by electrospinning, is coated by dipping into the suspensions with SiO₂ nano particles. The coated nano fiber is sufficiently dried in the shadow and sintered in the electric furnace among 300~500°C.

3. EXPERIMENTAL RESULT AND DISCUSSION

3.1 Producing the polymer nano fiber by electric radiation

Figure 4 shows SEM photographs of the electrospun nano fibers. The diameter of fiber is about 100~200 nm and the fibers show almost the same diameters. If the concentration of the PEO solution is very too low, the solution is sprayed and a lot of beads are formed and the diameter of fiber is thinned. On the contrary, if the concentration is too high, the viscosity acts strongly, so the diameter of fiber becomes



Figure 7: Scanning electron micrograph of the nano SiO₂ tube.

thick but beads are not formed anymore. If the electric field intensity is strongly acted on the polymer, and the emission of ions becomes strong. So the small diameter can be obtained by the electrical repulsion. Because the extremely high electric field intensity can cause electrical spark, there have certain limitation to choose appropriate electrical intensity.

3.2 The coating characteristics according to the SiO₂ concentration

Figure 5 represent the coating characteristics of nano fibers as a function of concentration of SiO₂ particles. The tests are performed in two case of 4 wt%, 6 wt%, and they show that the coating conditions are uniform all over the surfaces of nano fibers. In this paper, the tests are performed at the condition of 4 wt% of concentration.

3.3 Production of porous nano ceramic structures

Figure 6 shows the SEM of the HEPA filter, the PEO nano fiber and the porous nano ceramic structures. The HEPA filter consists of various fibers especially in diameter, and the PEO nano fiber shows uniform diameter of 100~200 nm. Figure

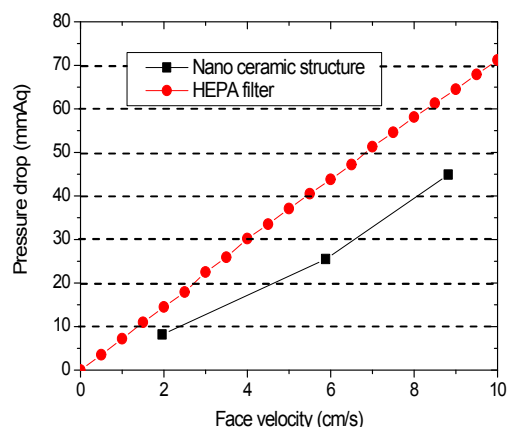


Figure 8: Pressure drop of nano ceramic structure.

6(c) and (d) show the nano ceramic structures produced at 300°C and 500°C, respectively. They show somewhat increased diameter compared with the PEO nano fiber. It because that the nano fibers were stacked and coagulated when they were in dip coating process. And there are no differences in the sintering temperatures.

Figure 7 shows a tube shaped nano structure and it is formed by the elimination of the polymer nano fiber. The tube shaped structure has weak mechanical properties than the fiber type structure, but it has chemical potential because it has enormous specific surface area, so if it is coated with TiO₂, then it will be useful to remove harmful gases.

Figure 8 shows pressure drop of the porous nano ceramic structure compared with HEPA filter as a function of face velocity. The porous nano structure shows slightly low pressure drop and it means it has low particle collection efficiency. But the air permeability is better. To analyze the characteristics of air permeability, moisture penetrations are measured and the value is 3.6 g/m²·h·mmHg. It is slightly higher than 2.4~3.2 g/m²·h·mmHg the value of Korean traditional paper(Hanji).

4. CONCLUSION

In this study, the HEPA type breathing wall is designed as a passive ventilation material to collect airborne particles and to supply fresh outdoor air and the following conclusions are obtained.

(1) The PEO nano fiber, which has 100~200 nm in diameter at the conditions of 10 wt% of concentration and 2 kV/cm of electric intensity, is produced by electro-spinning.

(2) The dip coating technology is confirmed in the solution with SiO₂ nano particles using polymer nano fiber.

(3) The polymer nano ceramic structures are produced by sintering the SiO₂ coated polymer nano fibers. The pressure drops are measured 8.2, 25.5, 44.9 mmAq at the velocity of 2.0, 5.9, 8.8 cm/s, respectively, and the humidity penetration is measured as 3.6 g/m²·h·mmHg which shows the possibility for the application of breathing wall.

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