공학석사학위 논문

Electric Air Filter for High-efficiency PM2.5 Capture with Metal Nanowire Networks

금속 나노와이어를 이용한 전기적 방식의 고효율 초-미세먼지 집진 에어필터 개발

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Abstract

Air pollution is one of most serious problem in today. Especially, particulate matter (PM) is representative and a lot of research tries to solve this. However, existing technology still have limitation such as high driving voltage, non-reusability and high pressure drop. In this study, we show novel electric air filter using metal nanowires to complement the drawbacks. Silver nanowires (Ag-NWs) with high aspect ratio form uniform conductive air filter. The pore size of Ag-NWs networks are under 10 μm, and the networks have excellent electrical and mechanical properties (5-7 Ω/sq) due to metal nanowires. For this reason, the filter shows high filtration performance (< 3-4 μg/m^3) for particulate matter under size 2.5 μm (PM2.5) and high air permeability through the filter. Also, the filter is reusable for several times according to simple dipping process in Ethylene glycol (EG).

Keyword : Metal nanowire, air filter, fine particulate matter

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Chapter 1. Introduction

1.1. Study Background

Today, environmental pollution has been a huge issue with scientific and industrial advance, and one of them is air pollution.[1-3] According to the improvement in quality of life, all over the world was gradually concerned about atmospheric environment.[4-6] Recently, people are conscious of seriousness of air pollution and it becomes one of the most important environmental problems as many research progressed about the harmful influence to body health, because the air is directly connected with breathing which is essential for life.[7-9] In generally, nose and respiratory tract filter the larger size of particles in air, but the smaller particles under size 10 μm (PM10) can pass through the body function and settle on lung. For this reason, air pollution causes a respiratory disease. More seriously, particles under size 2.5 μm (PM2.5) small enough to penetrate into lung and reach to alveolus and even blood vessel. The PM2.5 reached alveolus disrupts gas exchanging during breath process, and the fine-particles in blood vessel float and accrue continuously for long time. Of course it causes fatal lung disease and cardiovascular problems, and develops physical complications. The accumulated PM2.5 should be expelled from body for the solution, but smaller particles under the size 2.5 μm tend to adsorb easily and it is hard to desorb.[10-13] To prevent this problems, PM2.5 should be eliminated or filtered before it enter the body. A lot of research has attempted to approach the problems in various methods.

The methods can be divided into three types; scrubbing type, filter type and

electrical type. Scrubbing type has several limits for application such as need for enormous quantity of water, sewage treatment and corrosion. Which is why most research were about the electrical type and filter type. General Filter type system captures particles in air through combination of three principles; interception, impaction and diffusion. It uses simple operating system, and removal efficiency can be improved by multi-layers. However the filter has thickened for high performance, and it causes high pressure drop between before and after of filter.[14, 15] Also, the filter cannot be used in several times due to the damage while washing process. To complement this weakness of conventional filter type, Chong Liu et al. studied about thin, transparent and highly effective air filter.[16] The research team attempted several polymers to the filtration test, and determined the relation between polarity of polymer and removal efficiency. The filter showed not only high removal efficiency but also relatively high light and air permeability. However it still has problems of reusability. Lastly, electrical type system uses certain operating principle that consists of discharge and electrostatic attraction, therefore it shows the best performance among the three types. The attraction force by Coulomb's law is inverse second proportional to distance, and it is less-affected by distance in comparison to intermolecular force which is working mechanism of the filter in Chong Liu et al. research. Also, electrical type shows high removal efficiency for any size particles and low pressure drop. However, this type system need large equipment and high voltage over dozens of kV.[14] Thus, it has space restraints and explosion hazard for combustible gas. Besides, ozone (O3) which has toxicity to body was generated during discharge because of high voltage.

1.2. Purpose of Research

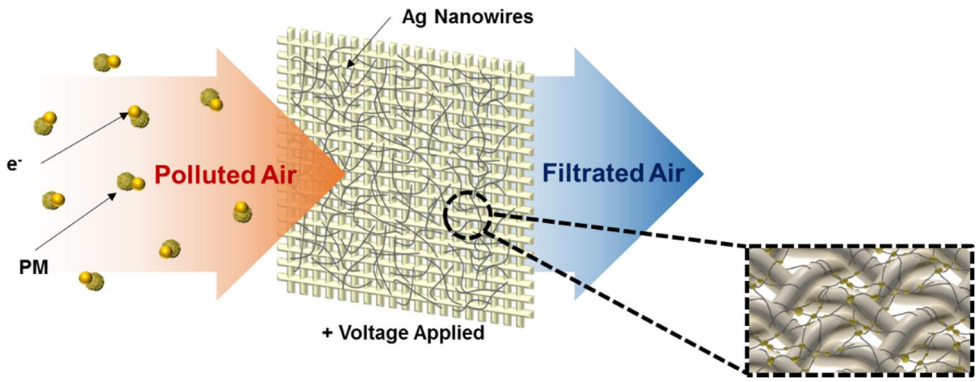


Figure 1. Schematic of working mechanism of the electric air filter using Ag-NWs.

In this research, we demonstrate a novel air removal technology utilizing the filter type and electrical type together with silver nanowires (Ag-NWs) to strengthen the strength and make up for the weakness. The Ag-NWs network has excellent electrical and mechanical properties, also it shows chemically stable in the atmosphere.[17-20] Besides the thickness of Ag-NWs are under 100 nm, and the network barely interrupts the flow of air through this. Using this nanomaterial, we made electric air filter with ag-NWs network for electrical type system (Figure 1). As compared to existing technology, it shows high removal efficiency even with lower voltage and power because the collecting surface of Ag-NWs is very close to the passing particles. By controlling voltage supplied to the air filter, we report PM2.5 concentration of after filtration in real times. Finally, we studied not only about improvement of efficiency but also reusability by washing. The used filter can be washed by simple dipping process in polar solvent such as ethylene glycol (EG). We conducted cyclic test about washing and attained unconverted conductivity and performance.

Chapter 2. Experiment

2.1. Preparation of Ag-NWs

Synthesis of long Ag-NWs (>100um in length, <100nm in diameter) employs modified polyol process using a one-pot process, where all reagents are dumped into a tri-angular flask at once, thus offering a facile and simple synthesis of long nanowires.[21] In 50 mL of ethylene glycol (EG), 0.4 g of PVP (Mw ~360,000) and 0.5 g of silver nitrate ($AgNO_3$) is sequentially dissolved using a magnetic stirrer. The stirrer is carefully removed from the mixture solution once all chemicals is thoroughly dissolved. An 800μL of $CuCl_2$ $2H_2O$ (3.3 mM) is rapidly injected into the mixture and stirred mildly. Finally, the mixture solution is suspended in a preheated silicone oil bath at 130 °C. The growth of Ag-NWs in the mixture is maintained at the elevated temperature for 3 hr. When the growth is finished, the resultant solution is cleaned using acetone and ethanol to remove the chemical residues along with centrifugation of 3000 rpm for 10 min three to four times. The purified Ag-NWs are re-dispersed in 1-propanol (IPA) for the use. The prepared Ag-NWs approximately show 2,000 aspect ratio (Figure 2(b)).

2.2. Fabrication of Electric Air Filter Using Ag-NWs

First, nylon mesh (Spectra/Mesh Nylon, 47 mm diameter, 53 μm opening) is used as a back-bone of the conducting air filter. The nylon mesh is sequentially washed with acetone and ethanol. After drying at room temperature for 10 min, we treat the mesh by low temperature oxygen plasma treatment 100 W for 1 min. Then Ag-NWs are transferred on the mesh by vacuum filtration method. Lastly, the mesh with Ag-NWs are heated at 120 ℃ for 10 min. Figure 2(a) shows the fabrication procedure.

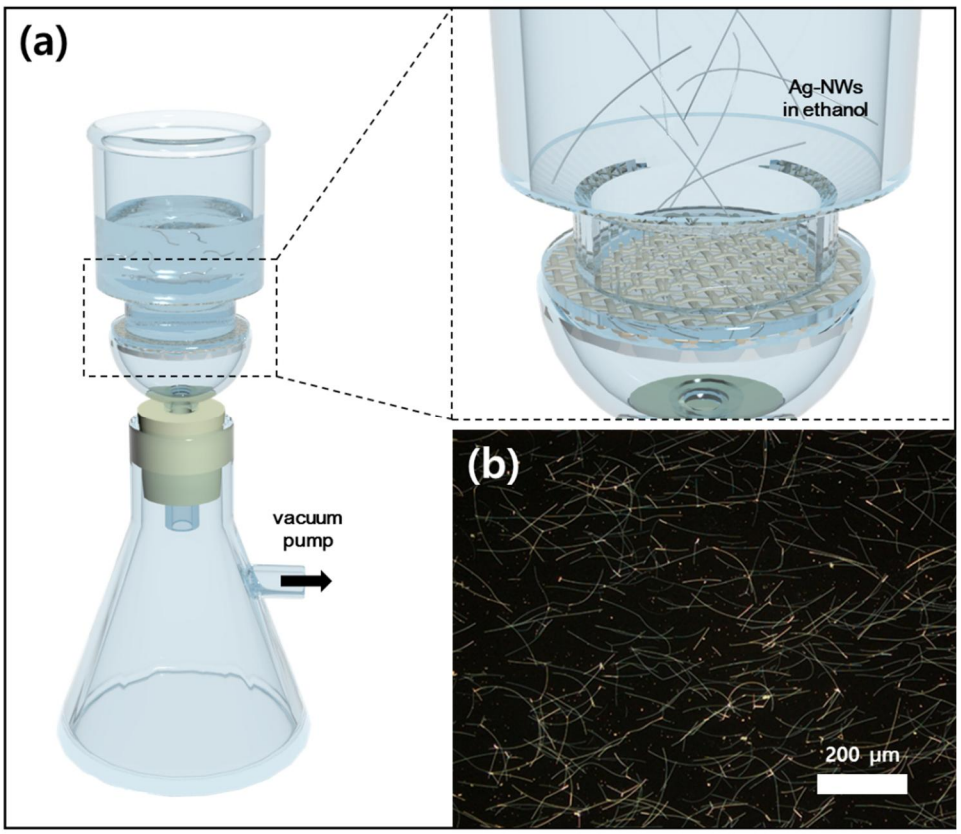


Figure 2. (a) Schematic of fabrication procedure of Electric air filter using Ag-NWs by vacuum filtration method. (b) Optical microscope image of Ag-NWs (Aspect ratio: 2,000).

2.3. PM Generation and Particles Density Measurement

According to previous study, Burning incense smoke generates PM particles and makes air condition high particles density. We do not dilute the smoke and continuously burn the incense inside the input chamber of experimental system for all test. As mentioned above, Input particles density exceed 1000 μg/m^3 and it is sufficiently dangerous to body health. In addition, filtration results of the air filter are measured by laser particle sensor module (Wuhan Cubic Optoelectronics Co. Ltd, PM2005). The particle sensor can measure both particles density of particle size 2.5 μm (PM 2.5) and 2.5-10 μm (PM10) simultaneously, and the value of PM 2.5 is used for all result data. The ionizer (TFB-YD1249) that is used for filtration experimental system is commercial small device for the parts of home appliance air purifier.

2.4. Cleaning the Used Electric Air Filter

The cleaning process is performed by using particular liquid state chemical. Ethylene glycol (EG) is available from Sigma-Aldrich and used without any purification. First, the used electric air filter is dipped into 20 mL EG for 30 seconds, and cleaned by water (H_2O) and ethanol. After that, we dry the cleaned electric air filter in 65 ℃ oven for 5 min.

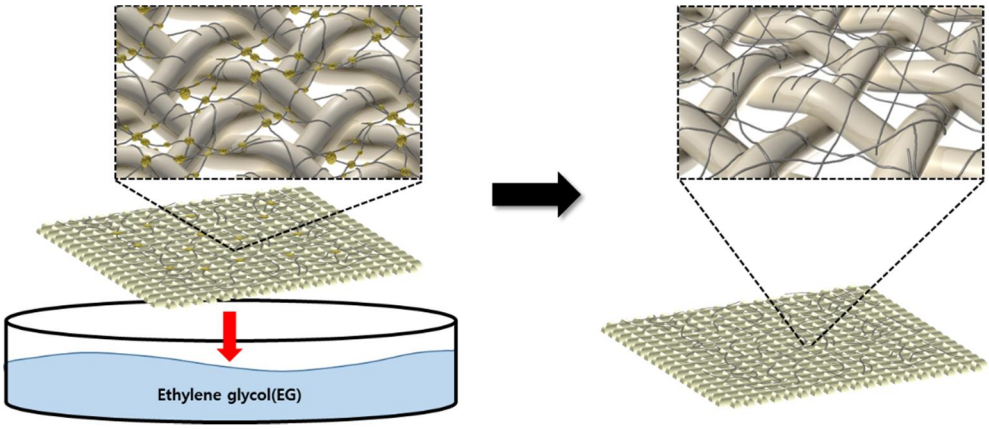


Figure 3. Schematic of cleaning process by simple dipping.

2.5. COMSOL Simulation

The air flow condition sets as 3 m/s of an incompressible laminar flow. A specific area ratio is measured as: net wires area per whole area (53 μm x 53 μm). The net wires area is calculated as: (the number of wires on the hole) x (area of individual Ag nanowire from SEM images). The diameters of nylon mesh and Ag nanowire is 40 μm and 100 nm, respectively. Spacing between individual Ag nanowires are considered as: whole length per number of wires.

2.6. Characterization

The surface structure and composition of as-fabricated ANN filter, ANN filer after PM filtration and ANN filter after cleaning process are observed with field-emission scanning electron microscopy (FE-SEM, Zeiss, Supra 55 VP) and energy-dispersive X-ray spectroscopy (EDX), respectively. The chemical property was characterized by FT-IR (Bruker, Tensor 27). The transmittance data is measured by UV-Vis spectroscopy (PerkinElmer, Lambda 650). The electrical resistance change is measured with source meter unit (Keithley, Model-2400).

Chapter 3. Results & Discussion

3.1. Electric Air Filter with Ag-NWs

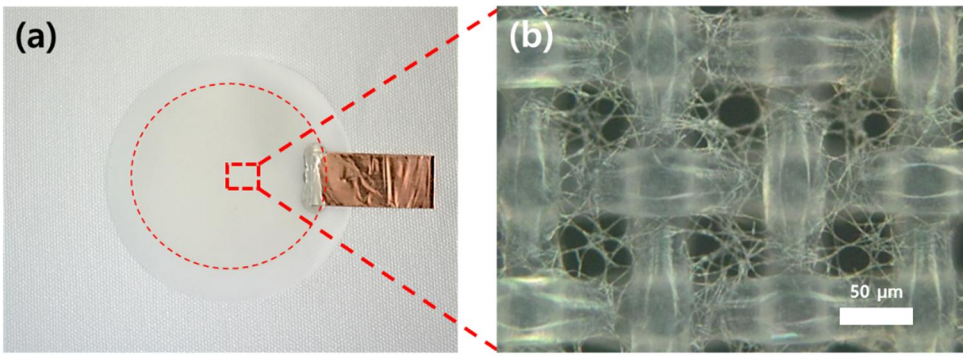
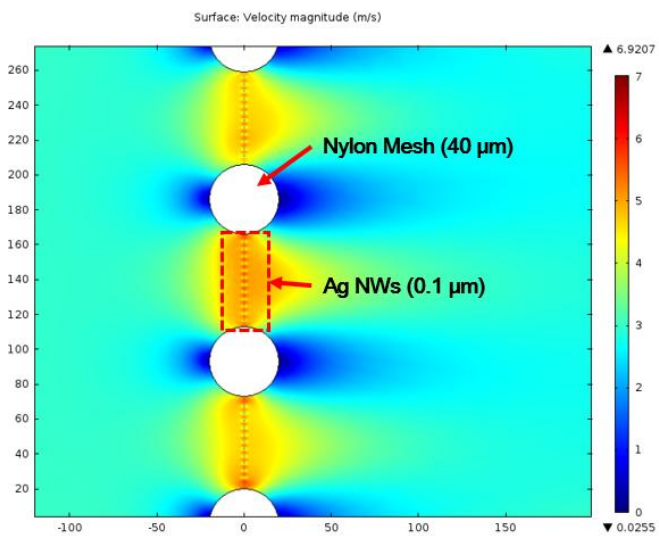


Figure 4. (a) Actual image of the electric air filter which shows little color difference between with or without Ag-NWs on back-bone. (b) Optical microscope image of structure of the fabricated air filter. The nylon mesh is completely covered with Ag-NWs.

In this research, Ag-NWs is used to form conductive networks for air filter. The Ag-NWs can be prepared through all-solution process that was previously reported.[21] Aspect ratio of the Ag-NWs is high enough to construct networks (Average thickness: 100 nm, Length: 200 μm). Figure 2(a) shows whole fabrication process of conductive air filter using Ag-NWs. We use nylon mesh as back-bone for Ag-NWs networks because the networks cannot be withstanding themselves. In addition, opening size of nylon mesh (53 μm) is appropriate to form Ag-NWs networks and show high air permeability. The Ag-NWs solution based on ethanol is transferred on the nylon mesh by vacuum filtration method, which result in randomly uniform networks. The electrical conductivity and average pore size of filter can be easily modulated by adjusting the amount of Ag-NWs solution. Then, the samples are heated for annealing and welding that enhanced electrical and mechanical properties. We use Ag-NWs with fixed quantity and set target resistance of the air filter under 5-7 Ω/sq. The overall fabrication process is simple

and fast compared to other process such as electrospinning.

To confirm the micro-scale formation of conductive air filter, actual image and Optical Microscope (OM) are analyzed. As shown in Figure 4(a), the color difference between the nylon mesh with ag-NWs and without cannot be easily distinguished. A small quantity of Ag-NWs is used for the air filter, but the conductivity is appropriate for the target value. In addition, the Ag-NWs form the networks uniformly on the mesh (shown in Figure 4(b)). The random networks cover the whole surface of fiber of the nylon mesh. Besides, the Ag-NWs that are longer than opening size of the nylon mesh set across the pores. In view of each pore, the networks are freestanding by the help of nylon mesh like spider web. This structure passes air through the filter without any disturbance, and make the



Specific Area Ratio (Wires Area/Hole Area)	0 %	2.5 %	5 %	7.5 %	10 %
Net Area of Wires (μm^2)	0	70.225	140.45	210.675	280.9
Number of Wires (#)	0	13	27	40	53
Pressure Drop (Pa)	20	51.93	110.24	200.25	290.05

Figure 5. COMSOL simulation for the electric air filter. The result shows pressure drop according to specific area ratio.

particles in air to contact the Ag-NWs on the nylon mesh during the passing.

2-dimensional simulation is performed to show an effect of pressure drops after passing through the ANN filter in Figure 5. The simulation is executed by increasing specific area ratio from 0 to 10 %. In here, the specific area ratio means net wires area per an individual whole area. Consequently, the pressure drop rate is proportional to the increased specific area ratio. The simulation result indicates that the pressure drop is 51.93 Pa at 2.5 % of specific area ratio, smaller than that of a commercial filter (300-800 Pa).[16] In fact, the specific area ratio of the ANN filter is measured as 2.69 % from SEM image analysis. Therefore, the randomly uniform ANN structure on the nylon filter is hardly disturbing air passing.

3.2. Results of Filtration Test for PM2.5

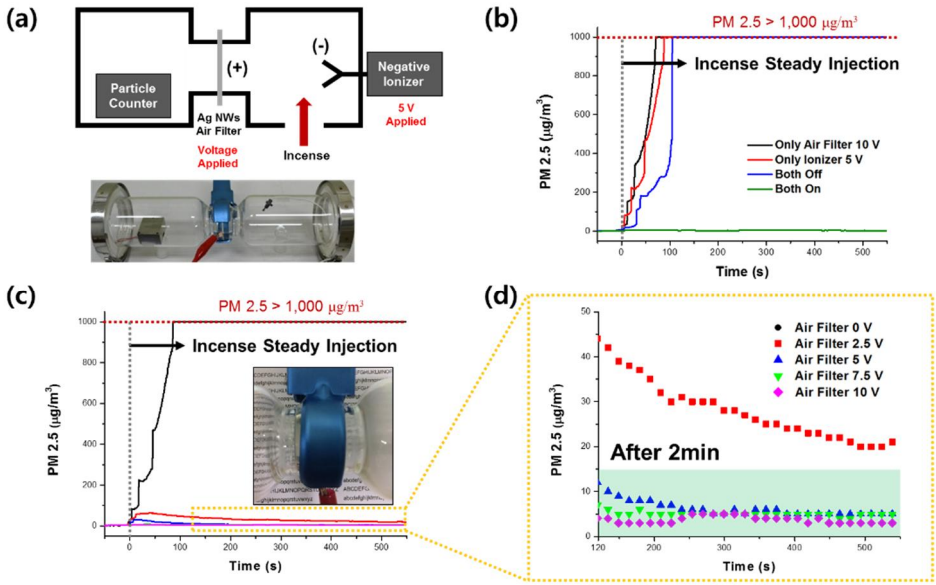


Figure 6. (a) Schematic of an experimental setup and actual image. (b) PM removal performance verified by simple on-off tests ; Only ionizer on, only 10V on the air filter, both on and both off. (c) The concentration of PM2.5 with various applied voltage on the air filter. (d) A yellow box area is replotted after 120 seconds from THE PM detection. The changes of PM density are detected up to 600 seconds with various applied voltage condition on the air filter.

As shown in Figure 6(a), we equip the experimental set-up in lab for this research and use it for all air filter test. The electric air filter with Ag-NWs is loaded between two chambers that the right side is input chamber and the lift side is output chamber. The upper side of the filter heads for input chamber. Negative ionizer is set input chamber for charging particles in the chamber with electrons. In addition, particle sensor, which is equipped in output chamber, communicates with computer to measure in situ real-time particle density of air. During air filter test, two power connect to the ionizer and air filter. Working voltage of the ionizer is fixed to 5 V and, voltage applied to the air filter is varied by the purpose of test. In addition, incense continuously burns in the input chamber while filter test. For this reason, particle density of input chamber is high, and measurement of the value is

insignificance (PM2.5 > 1000 μg/m^3). Particle density in the chamber after burning incense few seconds reaches to 1000 μg/m^3. According to this, the maximum value of meaningful measurement data is set to 1000 μg/m^3 for all test in this research.

To confirm the effect of ionizer and charging voltage to the air filter, particle density in output chamber of the lab-made set-up is measured in real-time, as shown in Figure 6(b). The incense burns from test start to end, and it injects particles consistently. Then, two supplied voltages to ionizer and charging voltage to air filter are turned on or off respectively. The both off case shows sharp increase and reach to 1000 μg/m^3 in 2 min. It means that particles in the input chamber easily pass the air filter by dispersion and the pore size of air filter is large enough to pass particles freely. The two cases that one is only charging 10 V to air filter and the other is only applying 5 V to ionizer also exhibit rapid increase. As this result, the ionizer does not influence on air filtration for itself. Meanwhile, the both on case which of setting was 10 V and 5 V to the air filter and ionizer respectively results in very low particle density under 10 μg/m^3 during the test. Photograph in Figure 6(c) is the image which close-up near the air filter between output and input chamber during the both on case. Input chamber was full of smoke, and it is harder to secure a view than output chamber. The particle density of input chamber is high enough to diffuse to output chamber, but the electric air filter obstruct the passage of particles. In addition, the particle density is measured in real-time as varying the charged voltage to air filter, as shown in Figure 6(c) and 6(d). In the case of 0 V applied to air filter, the particle density rapidly ascends to 1000 μg/m^3 as above. Whereas, the measured particle density with applying voltage (2.5 V, 5 V, 7.5 V and 10 V) shows relatively low values. Also, it shows the tendency that the measured value slightly increase in the initial time and decrease. In this experiment

with the set-up, it needs a period of time to reach stable state. Moreover, the data after a few minute is significant due to the initial stage of burning incense and filling the input chamber. In addition, a major cause of the decrease is that the electric air filter pulls particles in output chamber and collects them. For the reason mentioned above, the graph data is magnified to exhibit after 2 min on Figure 6(d). It focuses on the results of air filter test with varied non-zero voltage (2.5 V, 5 V, 7.5 V and 10 V) to establish interrelation between particle density of output chamber and voltage applied to air filter. With 2.5 V applied to the air filter, the particles density after 2 min (PM2.5 < 50 μg/m^3) is greatly lower than that of the case with 0 V and gradually declines to 18-20 μg/m^3. Only applying slight voltage to the air filter remarkably improves filtration effect. Furthermore, the result of air filter with higher voltage than 5 V exhibits lower particle density, under 10-15 μg/m^3. Specifically, the result value with 7.5 V and 10 V show about 5-7 μg/m^3 and 3-4 μg/m^3 respectively. According to this result, the filtration effect depends on the voltage applied on air filter. The higher the charged voltage, the better filtration effect. Besides, it shows that the time, which the set-up take to reach the stable state with higher voltage, is shorter than the time with lower one. This experiment shows excellent filtration effect and stability of electric air filter with relatively high voltage.

3.3. Mechanism of Filtering and Washing of Electric Air Filter

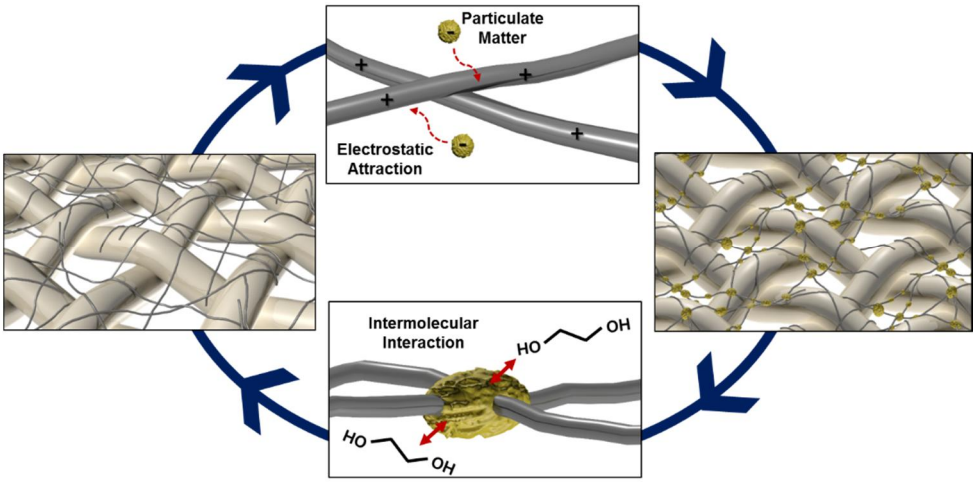


Figure 7. Schematic of mechanism of filtering and washing of electric air filter.

Figure 7 shows the mechanism of filtering and washing electric air filter as series of schematics. At first, Particles fill the air in input chamber by burning incense. Then, near the negative ionizer, the particles accept electrons and have electric negative charge. At the same time, positive voltage relative to the ground that is shared with ionizer in circuits is applied to the electric air filter with Ag-NWs. As a result, the particles and electric air filter have opposite charges and it causes electrostatic attractive force each other. When the particles close to the air filter and try to pass it, the air filter catches them with the electrical method. Particularly, Ag-NWs are used as conductive part at the air filter. The particles in air must pass through the networks of Ag-NWs, and the distance between the particles and Ag-NWs is close enough to catch them easily. In addition, Electrical and mechanical properties of the air filter are enhanced by using Ag-NWs. Besides, the surface exposed to particles in air (Surface to volume ratio) is larger than general plane

electrode. For this reason, it increases amount of particles caught on them. After the filtration, we dip the used filter in ethylene glycol (EG) to clean the caught particles. EG solves the particles adhered on the surface of Ag-NWs in a few second without mechanical stimulation.

In theoretically, strong electrostatic attraction is occurred between the PM and the air filter in Equation 1.

$$K_{\varepsilon}\frac{q_1 q_2}{r^2} = F \text{ ; (Coulomb's Force); Eq.1}$$

$$\frac{-m_1^2 m_2^2}{24\pi^2\varepsilon_0^2\varepsilon_r^2 k_b T r^6} = V \text{ ; (Keesom Equation); Eq.2}$$

In contrast, in the previous study, the major mechanism for the PM capture is originated from the intermolecular interaction, which caused from the permanent dipoles of polymer filter and PMs.[16] As shown in the Equation 1 and 2, interaction force is much smaller than Coulomb's force. Therefore, PM removal efficiency is lower than the electrostatic-based filter system. Instead, we use the intermolecular interaction for the cleaning of the used filter. The intermolecular interaction between dipole solvent and PM is high enough to tear off the PMs from the filter.

To confirm the result of filtration and cleaning of electric air filter, we perform scanning electron microscope (SEM) and energy dispersive X-ray spectroscopy (EDX) analysis to characterize the samples. The figure 8(a) shows SEM image of unit cell of air filter before filtration test. The Ag-NWs form networks uniformly on nylon mesh and over the pore, and connect well each other. Also, SEM image of air filter after filtration test and before cleaning is on figure 8(b). PM particles adhere to the surface of Ag-NWs like a water drop on a web. It becomes bigger with

continuous catching of new particles, and merges with together in shape of sphere. Specially, intersection spot of Ag-NWs collects more particles and is covered with bigger mass of them than the other area. The collected shape and merging process of particles is similar with the polymer air filter that we mention in the above.[16]

EDX

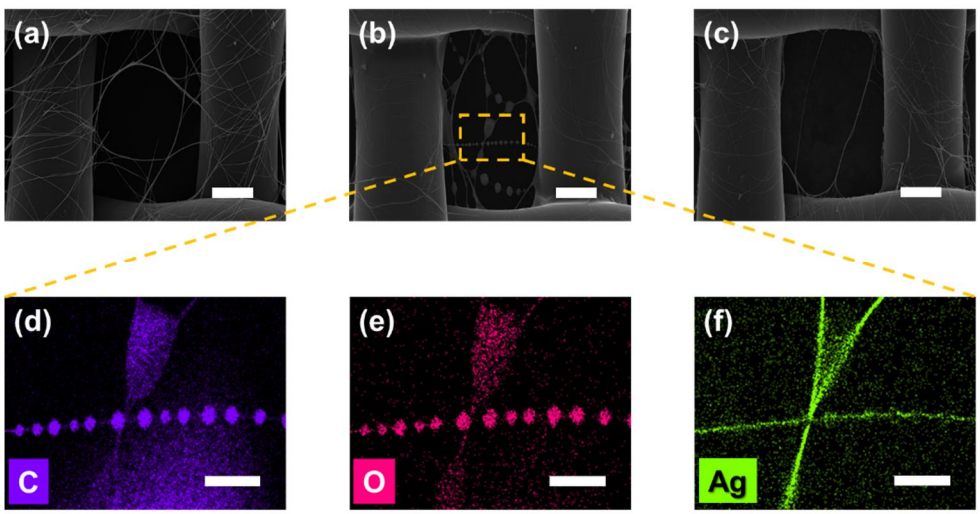


Figure 8. SEM images showing Ag nanowire transferred air filter (a) before PM particles capture, (b) after PM particles capture and (c) washed by ethylene glycol and ethyl alcohol for reusable air filter (scale bar: 20um). In the SEM image of PM particles captured Ag nanowire air filter, EDX element mapping of (d) carbon, (e) oxygen and (f) silver. (Scale bar: 6um)

element mapping image about carbon (C), oxygen (O) and silver (Ag) are shown in Figure 8(d), (e) and (f) respectively. According to this data, C and O constitute the mass collected on the surface of Ag-NWs, and Ag-NWs still exist without shape-change. Through this, we confirm the capture of particles on Ag-NWs. Also, the particles cover all over the surface of nylon mesh fiber not only the Ag-NWs as shown in Figure 9(a). The reason for this is that the Ag-NWs on surface of the fiber attract particles with the electrical method and they attach to the nylon by dipole-dipole intermolecular force between them.[16] At last, Figure 8(c) shows the SEM

image of air filter after cleaning. The collected particles on the surface and intersection spot of Ag-NWs disappear after cleaning with EG, H_2O and ethanol. The Ag-NWs still form networks all over the air filter and are slightly damaged during the cleaning process. Also, the particles covering the surface of nylon mesh fiber dissolved into EG as shown in Figure 9(b).

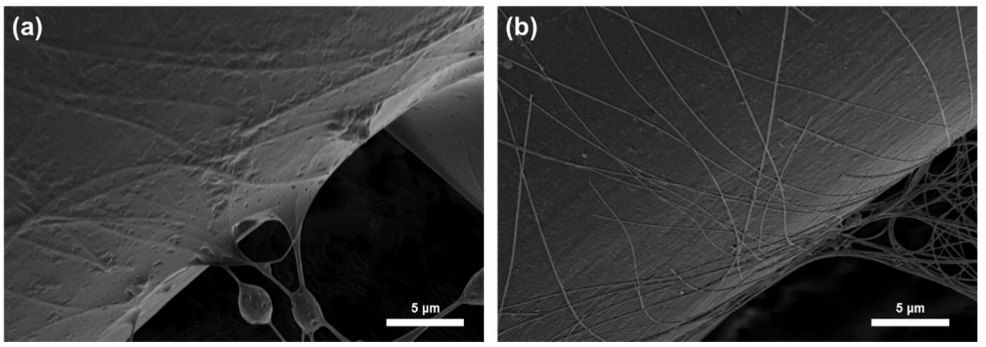


Figure 9. SEM image of nylon mesh fiber surface of Ag-NWs transferred air filter. (a) After PM particles capture, and (b) cleaned with EG, H_2O and ethanol.

3.4. Characterization

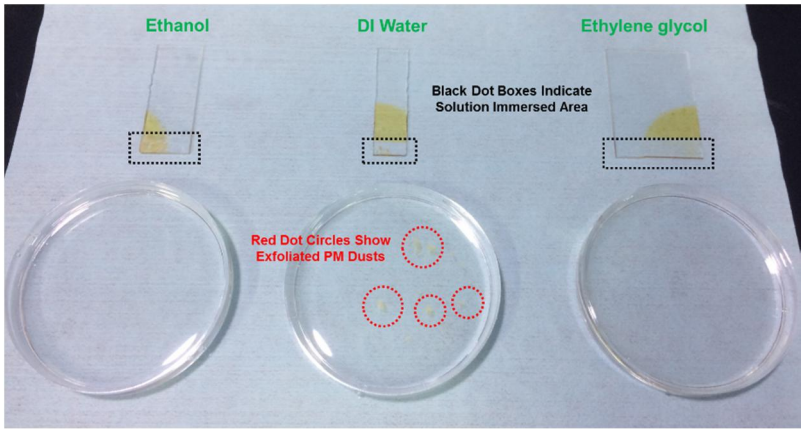


Figure 10. PM Particle Solubility on the glass by solvent (Ethanol, Water, EG).

In previous study, the solid polymer with high dipole moment like Nylon-6, polyacrylonitrile (PAN) and polyvinylpyrrolidone (PVP) was used to catch PM 2.5 particles.[16, 22] The efficiency of filter using the solid polymer was higher as the dipole moment of solid polymer increased. In this research, intermolecular forces by dipole moment operated on separation of filter and PM particles for cleaning as inverse concept. Liquid state solution with high dipole moment was used for the separation, because its intermolecular forces can directly act on particles with permeation and hydration. As shown in Figure 10, the collected particles on glass was soaked in ethanol, H_2O and EG to confirm solubility of particles. In a chemical properties of these solutions, dipole moment values were 1.69, 1.85 and 2.36 in unit debyes (D) respectively. Ethanol slightly affected the collected particles, and remained it on glass without available change. In the case with H_2O, it dispersed

the particles in relatively large visible mass. Whereas The EG solution simply dissolved the component of particles in a few seconds. On the base of this, the liquid solution with higher dipole moment solved the mass of particles better and faster due to the stronger intermolecular force.

The optical characteristic is examined for as-prepared air filter, PM2.5 particles captured air filter and the filter after cleaning process by using UV-Vis and FT-IR. Figure 11(a) represent optical transmittance differences of the filters. An obvious peak difference observed in wavelength region of 250-400 nm for the air filter after filtration and cleaning process, which corresponds with the inset images. The transparency is slightly decreased after cleaning process, however, a similar peak trend is maintained. Figure 11(b) suggests that as-prepared air filter and cleaned air filter has analogous spectrums while PM2.5 captured filter shows different signal trends in around 900-1,800cm^{-1}. Inset exhibits actual digital images of PM2.5 captured air filter and cleaned air filter, respectively. The visual color of cleaning-processed air filter becomes much brighter and colorless. Therefore, the cleaning process by using polar solvent is successfully demonstrated in optical point.

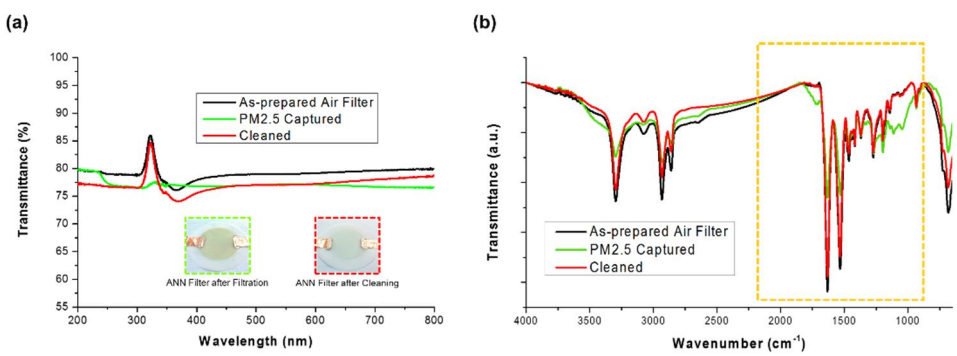


Figure 11. (a) UV-Vis results and (b) FT-IR analysis of as-prepared air filter, PM2.5 captured air filter and the filter after cleaning process. FT-IR results indicate that the cleaning process by using polar solvent is successfully demonstrated. The

Insets are ANN filter after PM filtration and after cleaning process, respectively.

3.5. Cleaning for Used Filter with Simple Dipping Process

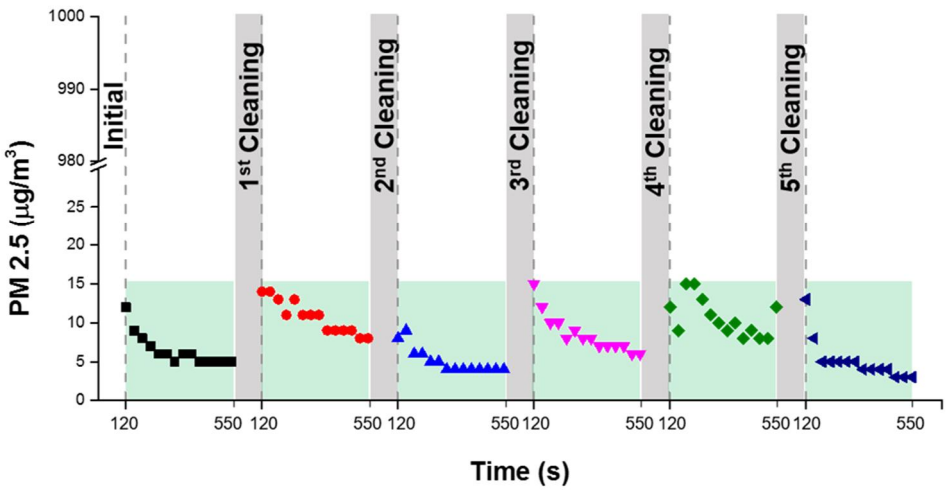


Figure 12. 5-time cyclic PM removal performance test with polar solvent cleaning process. The PM density is investigated after 120 seconds for the each of the PM filtration test.

To confirm the durability and reliability of the electric air filter about cleaning process, we performed cyclic test which repeated filtration and cleaning. The process that was shown in Figure 7 was repeated more than five times, and the power supplied to ionizer and air filter was fixed to 5 V. Each filtration test was performed for 15 min, and the particles sensor consistently measured density of particles in output chamber. After the each test, the both chamber (Input and output) is washed by cleaner, acetone, ethanol and deionized-water in this order. As mentioned above, the measurement values from 120 to 550 sec were analyzed and sequential data graph with time was shown in Figure 12. All result density of

particles was under 15 μg/m^3, and the values decreased continuously after 120 sec. Also, the minimum value of each test was under 10 μg/m^3. Besides, the performance of air filter after 5th washing was approximately equal to the result of initial test. According to this, cleaning process had no influence on performance of the electric air filter. In addition, resistance of air filter was measured after cleaning each times to confirm the effect of cleaning process on electrical properties of the air filter. We made two electrode at opposite ends of the samples as shown at inset image in Figure 11(a), and measured resistances between the both (see Figure 13). The initial resistance (R_0) and the value after 5th washing were 5.66 and 6.43 Ω/sq, respectively. The maximum value was 6.92 Ω/sq after 3rd washing. Resistance was slightly changed without any tendency. During the cleaning process, structure of Ag-NWs network on nylon mesh barely changed according to the wetting and drying. Above all, the filter was damaged while we loaded the samples on set-up and handled it for cyclic test. Despite of this effects, major frame of the structure maintained the form of it. In conclusion, the electric air filter shown excellent durability and reliability according to this test.

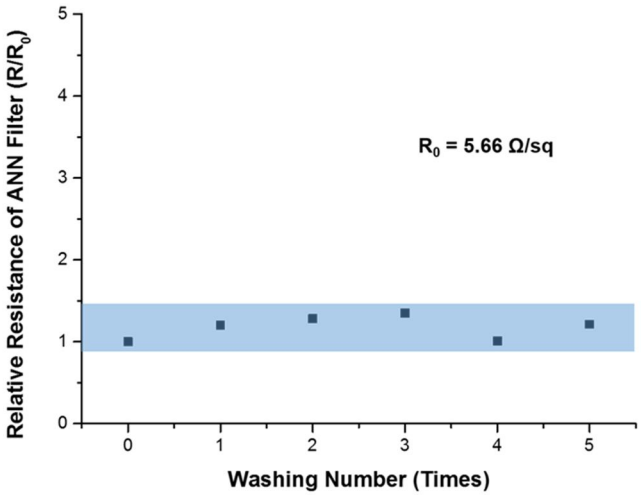


Figure 13. The normalized electrical resistance shows few changing rate after the cleaning process. The sheet resistance changes on the electric filter shows low influence for the PM removal performance.

Chapter 4. Conclusion

We have demonstrated that Ag-NWs networks can be high-performance electric type air filter for PM 2.5 due to the high conductivity and aspect ratio of Ag-NW. According to real-time measurement, the fabricated Ag-NWs electric air filter shows higher filtration efficiency compared with commercial air filter only by single layer. The performance is remarkable even with low voltage (under 5V), and it can be improved more by increasing voltage supplied to the filter. In addition, we have developed facile cleaning process with polar solvent for the used air filter. As result of successive test, the excellent recyclability of air filter is proved. The above performance ensures that the electric air filter can be used as highly efficient

blocking layer for PM2.5. Such as portable high-performance mask in lab and industry or air filter in car, the novel air filter would be worth for various application. We anticipate that the Ag-NWs networks electric air filter will make large contribution toward solving air pollution with PM2.5.

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초록

산업화가 급격히 진행됨에 따라 대기오염은 가장 심각한 문제 중 하나로 떠올랐다. 대표적인 대기오염 물질로서 미세먼지(Particulate matter, PM)가 있으며, 개선을 위해 많은 연구들이 진행되어 왔다. 그러나 기존의 기술은 높은 요구 전압, 재사용의 어려움, 높은 압력 강하 등 여전히 한계점을 지니고 있다. 이를 위해 본 연구에서는, 전기적/기계적 특성이 우수한 고-종횡비의 금속나노와이어를 이용하여 전기적 방식의 에어필터를 개발하였다. 개발된 에어필터는 낮은 전압(< 5V)에서 PM2.5에 대한 높은 필터 효율(< 3-4 μg/m^3)을 보인다. 또한 기존의 필터 기술과 달리, 극성 용매를 이용한 세척 공정 기술 개발을 통해 본 필터의 재사용이 가능하다. SEM, EDX, UV-vis, FT-IR 등 다양한 분석을 통해 개발 필터의 필터링/세척 전후의 표면 구조 및 화학적/광학적 특성 변화를 확인했다. 본 개발 필터는 여러 번의 세척 공정에도 미비한 손상을 보이며, 변함 없이 높은 효율과 전기적/기계적 내구성 및 안정성을 보인다.

Key word : 금속나노와이어, 에어필터, 초미세먼지

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