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FLY ASH INCORPORATED POLYURETHANE ELECTROSPUN MEMBRANE FOR CO_2 ABSORPTION

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In this study, we reported a composite electrospun membrane fabricated by impregnating FAP into polyurethane fibers for the adsorption of CO_2 from the atmosphere. The samples were prepared 0, 40, 60 wt% of FAP with respect of PU and evaluated on a reduced scale (1/10) of actual product. The membrane has been characterized as a porous and high surface area substrate having effective adsorbent capacity. The composite electrospun membrane was characterized using various analytical techniques, including field emission scanning electron microscopy (FE-SEM), transmission electron microscopy (TEM), X-ray diffraction (XRD), and FT-IR spectroscopy. The results show that PU/FAP composite mat containing 60 wt% FAP can decrease CO_2 level by 32 % in half an hour compared to the pristine PU. The absorption of CO_2 was attributed to the presence of FAP into PU fiber. Present technology utilizes FAP to fabricate an eco-friendly membranes and could be applied for air filtration from.

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1. Introduction

In recent years, electric automobiles have been researched actively to match better performance such as high power supply, and lower fuel consumption. Thus, effective methods to enhance fuel-efficiency of vehicle and to reduce air pollution have been needed for a profound solution [1-5]. Because interior space of automobiles is enclosed, toxic pollutants for human body such as volatile organic compounds (VOCs), carbon oxide (CO_2) could be easily amassed [2-3], and careless of treatment may cause serious problems in human health. Therefore, driver should open the windows repeatedly in order to have a fresh air into the vehicle. Many studies have been carried to increase the mileage of vehicle by different ways such as air control of indoor using of new alternative materials [6-7].

In winter, the air control mode during driving is used form outer air to keep indoor fresh air condition. In case of gasoline car, the loss of energy consumption doesn't matter at air conditioning because heat core is operated with cooling water. However, electric automobile has a huge loss of power by operating positive temperature coefficient (PTC) heater motors [8-9]. Therefore, new researches are required not only minimize the energy consumption of PTC motor with recirculation heated indoor air, but also make indoor air fresh by removing the excreted CO_2. Fly ash is waste materials and is produced from higher temperature in power plants and has the absorption property. Thus fly ash (FA) is a eco-friendly, costless and easily available. When FA is incorporated with polymer, its property may be promoted effectively in the absorption effects [10-

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12]. The amount of CO_2 might be reduced, without power loss, using a novel membrane of polyurethane (PU)/fly ash (FAP) composite fabricated by electrospinning process.

This study describes the fabrication of a novel membrane to capture CO_2 gas from circulating interior which is prepared with polyurethane and inorganic material of fly ash particles (FAP) using electrospinning process. The reduction of CO_2 from air was achieved without any additional power consumption and higher expenses.

2. Experimental setup

2.1 Material

Commercially available PU pellets (Estane® Skythane® X595A-11, Lubrizol Advanced Materials, Inc., USA) and purified fly ash particles (FAP) obtained from Won Engineering Company Ltd. (Gunsan, Korea) were used as received. N,N dimethylformamide (DMF) and methyl ethyl ketone(2-butanone) (MEK, extra pure) were purchased from Showa Chemical Co., Ltd., Japan and Junsei, Japan, respectively, and were used as solvent. .

2.2 Electrospinning

Ball-milled FAP (using 3 mm zirconia balls and sieved for 12 h) and PU pellets were used after drying for at least 3 h at 80˚C. 10 wt% PU solution was prepared in DMF/MEK (50:50 by weight). Different amounts of FAP (0, 40 and 60 wt% with respect to PU) was added to the PU solution and magnetically stirred for 3h and sonicated in wather bath for 3 h to make homogenous solution. Electrospinning was carried out using the set-up as in shown of Fig. 1. The different samples of electrospun mats were fabricated using multi nozzle in the electrospining system which is controlled the spray angle for functionally graded membrane (FGM). The electrospinning parameters include 15 kV applied voltage, tip-to-collector distance of 18 cm, and solution feed rate of 1 ml/h. After electrospinning, the nanofibrous mats were dried in vacuum drying for 12 h at 30˚C. The dimension of samples is evaluated on a reduced scale by 1/10 compared to actual size of automobile. Samples are fabricated in A4 size (210×297 mm) considering the same size of inlet air filters of automobile and are attached on the supporter made separately to enhance experimental efficiency.

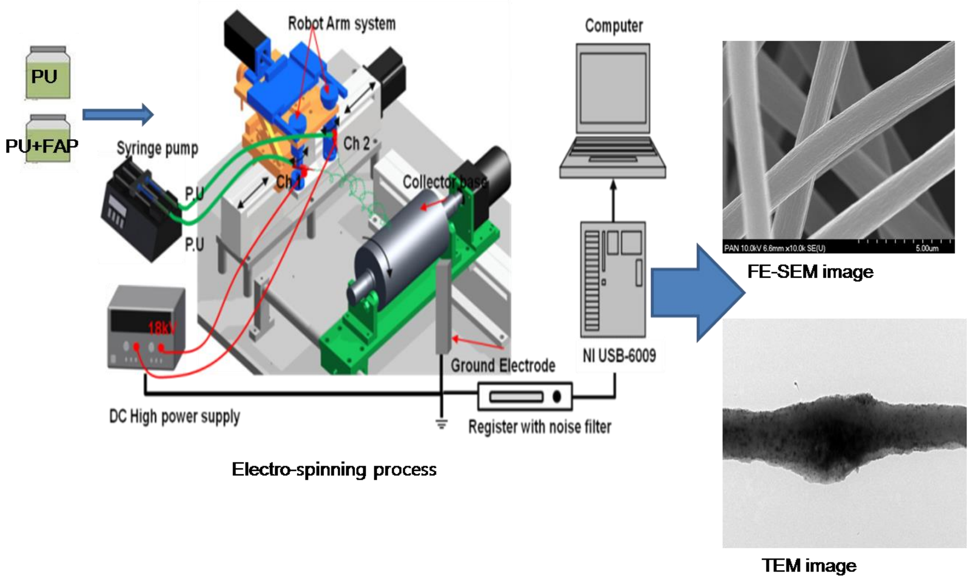
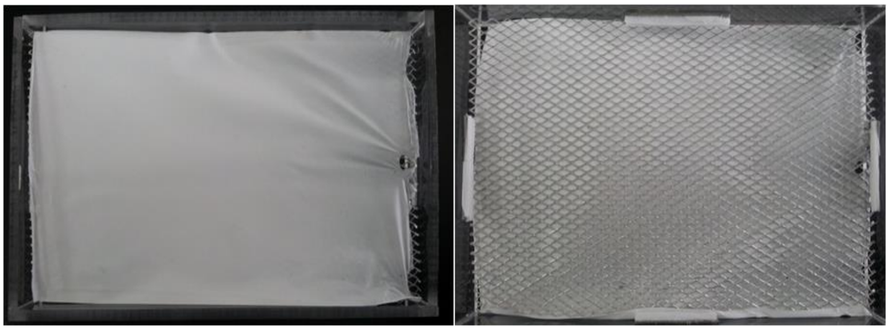


Fig. 1 Schematic of experiment equipment



(a) (b)

Fig. 2 the images of sample mat of (a) front panel and, (b) rear panel

2.2 Experimental system

Fig. 3 shows the experimental setup to measure the absorption performance of different fibrous samples. As illustrated in Fig. 3, the system was designed with inlet valves to control in gate and sensors of CO_2 for measuring the rate of gaseous distribution and drain valves to emit CO_2 gas after experiment. Test equipment is made up with transparent acrylic materials to check visual effect. And, every edge was bonded to silicon not to be discharged.

Meanwhile, we used Senselife Tim-8 of Hana Engineering and USB DAQ-6008 board with Lab VIEW of National Instrument (US) to measure the output value of sensor.

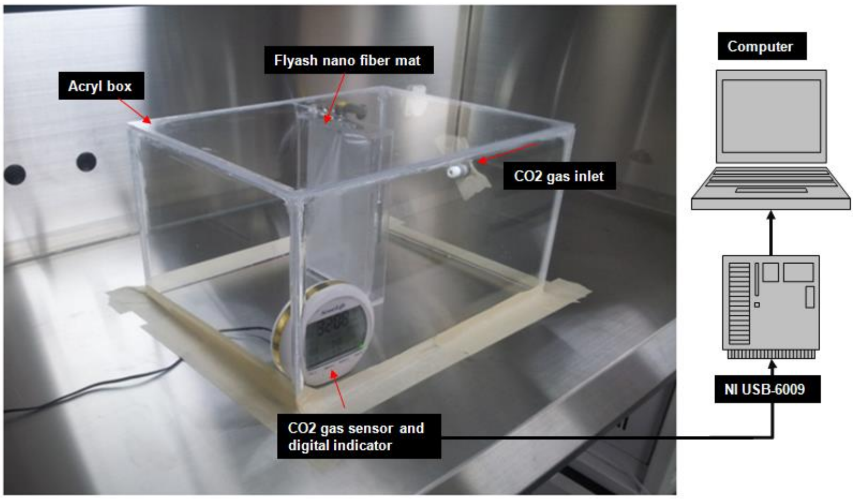


Fig. 3 Real experiment configuration and DAQ flowchart

2.3 Characterization

The surface structure and morphology of the present FAP composite powder were studied by field emission scanning electron microscopy (FESEM, S-7400, Hitachi, Japan), and X-ray powder diffraction (XRD) analysis was carried out by a Rigaku X-ray diffractometer (Cu Ka, l ¼ 1.54059 A) over Bragg angles ranging from 20 to 80 degree. Fourier transform infrared spectroscopy (FTIR) spectra of the samples were obtained using a Paragon 1000 Spectrometer (Perkin Elmer). The signal resolution of the FTIR was 1 cm-1 and a minimum of 16 scans was obtained and averaged within the range of 400–4000 cm^{-1}.Thermo-gravimetric analysis (TGA, TA Instruments, and USA) was carried out to check for the thermal stability of the samples at a heating rate of 10 °C/min from 30 to 600 °C.

3. Results

3.1 characterization of composite fiber containing FAP

FE-SEM images of different mats containing FAP are illustrated in Fig. 1. Diverse shaped FAP were incorporated into PU by the electrospinning a blend solution of PU and FAP. The morphology of the pristine PU showed a smooth and porous structure and the fibers were distributed into a wide range of 240-600 nm in a diameter while the morphology of the PU/FAP composite showed the deposition of particles into the nanofibers. The fiber diameter was decreased with increasing the amount of FAP into the blend solution; the fiber diameter of PU including 40 wt%, and 60 wt% is 220-350 nm and 182-430 nm, respectively. Decrease in fiber diameter might is attributed to the decreased conductivity and increased viscosity of blend solution with increasing the amount of FAP [13]. Therefore, it was considered that the morphology of 40 wt% FAP had a stable structure for the application.

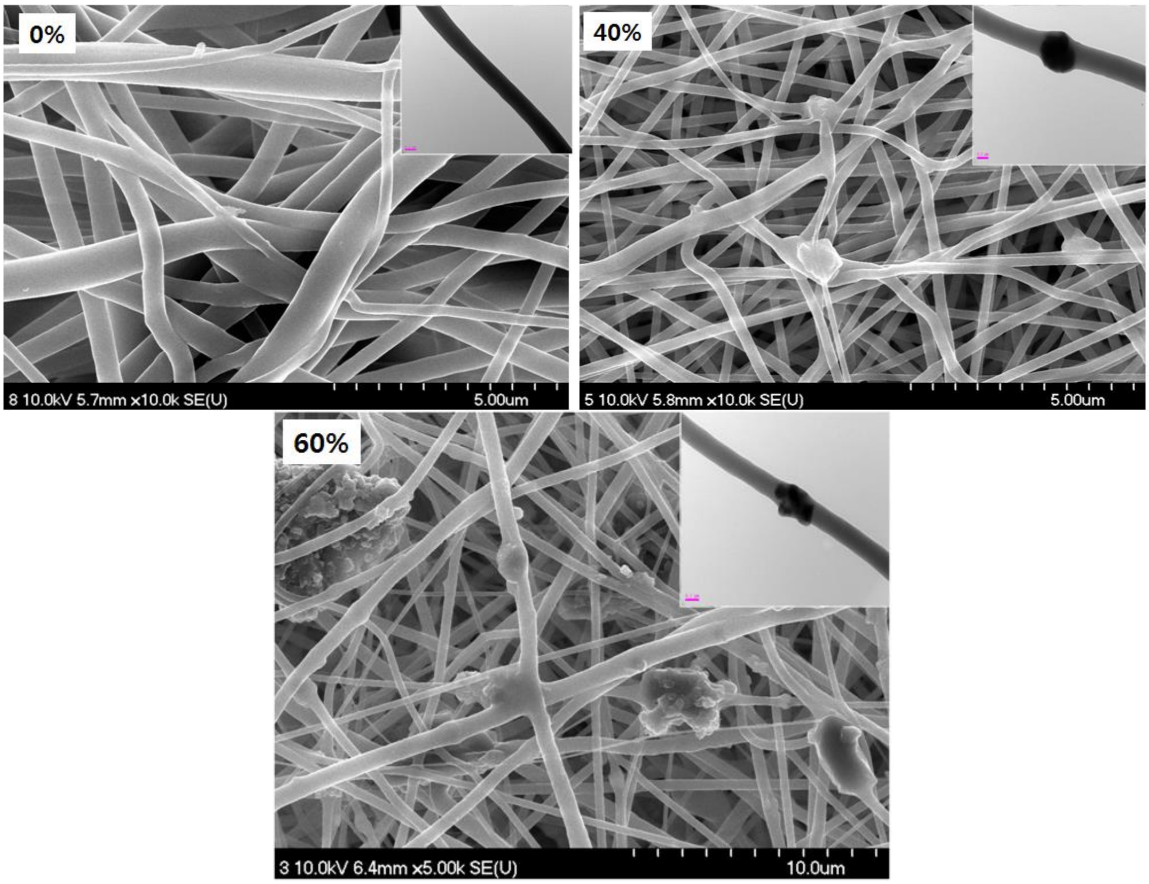


Fig. 4 FE-SEM images of (a) Pristine PU, (b) PU/FAP 40wt%, and (c) PU/FAP 60 wt%

3.2. XRD analysis

To investigate the composition of the composite fibers, the XRD spectra of different PU/FAP composite mat was measured as shown in Fig. 5. The pristine PU mat (Fig. 5a) did not showed a specific peak while PU fibers containing FAP show the existence of mullite and crystal structure [14]. The peak intensity was increased with increasing the amounts of FAP in a composite mat revealing the impregnations of FAP into the PU nanofibers.

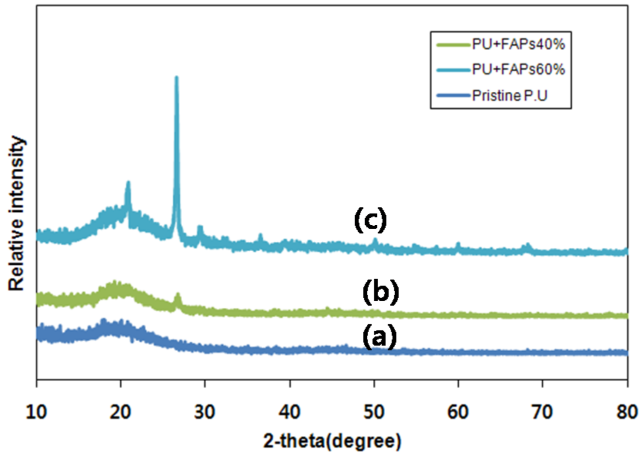


Fig.5 XRD spectra of (a) pristine PU, (b) PU+FAP 40 wt%, and (c) PU+FAP 60 wt%

3.3 FTIR analysis

Furthermore, to analyze the composition of different nanofibers, and to investigate the possible interactions between PU and fly ash particles, we took FTIR spectra of the samples as shown in Fig. 6. The curve of PU mat has typical characteristics [15]. However, the FTIR spectrum of PU/FAP composite mats had a tendency of shifting toward higher value of wave numbers due to interaction of hydrogen between different particles [16]. The maximized value of peak indicated at a PU/FAP of 60 wt%. It was observed that an increase of FAP was shifted toward a higher direction.

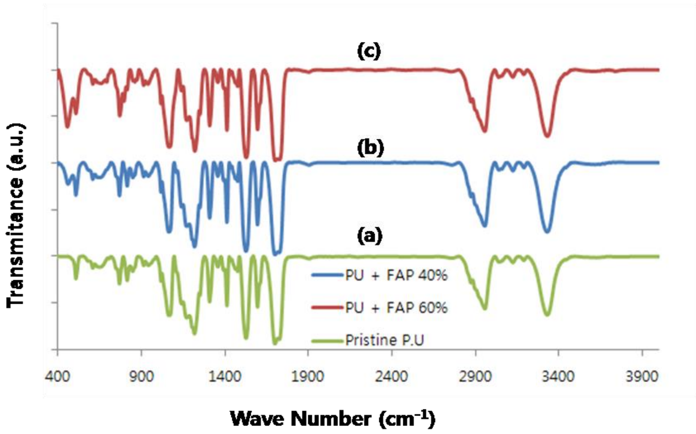


Fig. 6 FTIR spectra of different mats (a) Pristine PU, (b) PU+FAP 40wt%, and (c) PU+FAP 60 wt%

3.4 TGA analysis

Additionally, the presence of FAP into PU solution was analyzed to investigate thermal stability by the thermo-gravimetric (TGA) as showed in Fig. 7. It was observed that the thermal degradations of the PU/FAP composite fibers were shifted towards lower temperature and more amount of residue was remained on incorporation of FAP on the polymer matrix. Moreover, the amount of residue was increased when more amount of FAP was impregnated into the fiber matrix. This result confirms the incorporation of FAP into the fiber matrix.

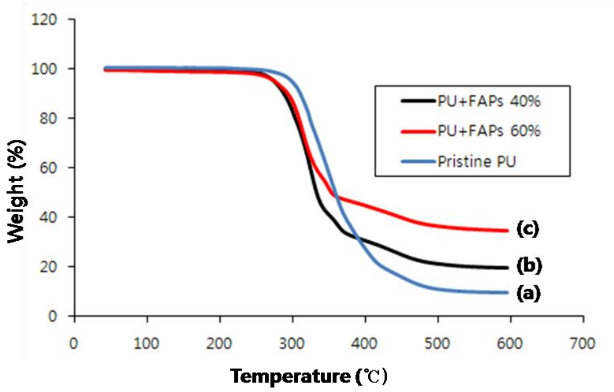


Fig.7 TGA curves of different mats (a) Pristine PU, (b) PU+FAP 40wt%, and (c) PU+FAP 60 wt%

As demonstrated by diverse analyses of FE-SEM, XRD, FTIR, and TGA, the presence of inorganic materials into polymer matrix have characterized strong intensity and conspicuous configuration.

3.5 CO_2 filtration test

The different samples were evaluated on the compacted container as illustrated in Fig. 3. The results of CO_2 absorption evaluation were compared (Fig.8). It has been clearly observed that the pristine PU mat negligible efficiency for the absorption of CO_2 while PU composite mats had excellent efficiency. The PU mat with 60 % wt FAP was found to have high efficiency for absorption of CO_2, thus reducing its amount. The CO_2 amount was significantly reduced by 32 % in 10 min and 35 % in 30 min with compared to pristine PU mat. This result clearly suggested that the incorporation of inorganic material (FAP) in the PU nanofiber. To signify the experimental results, the position of samples was changed to two different directions such as vertical, horizontal location, but the results are similar as was conducted in shown Fig. 8.

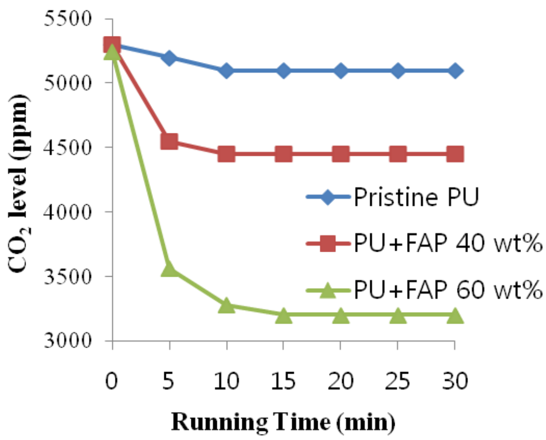


Fig. 8 Experimental CO_2 evaluation results of different mats (a) Pristine PU, (b) PU+FAP 40wt%, and (c) PU+FAP 60 wt%

4. Conclusion

The electrospun PU/FAP composite mat was fabricated for removing CO_2 component from air. The experimental methods were considered to a reduced scale (1/10) of actual product for automobile model. Field emission scanning electron microscopy (FE-SEM), X-ray diffraction (XRD), and FT-IR spectroscopy and thermogravimetric analysis showed the impregination of FAP into the PU nanofibers. As-fabricated membrane was highly effective for the reduction of CO_2

level by 35 % compared to pristine PU. Therefore, as-synthesized PU/FAP composite could be a potential interior material and be applied for air filtration.

Acknowledgements

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