미세먼지 포집과 포름알데히드의 동시 측정을 위한 나노섬유 필터
- Dual-functional self-assembled electrospun nanofiber filters for PM removal and formaldehyde sensing simultaneously -

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Introduction

Background

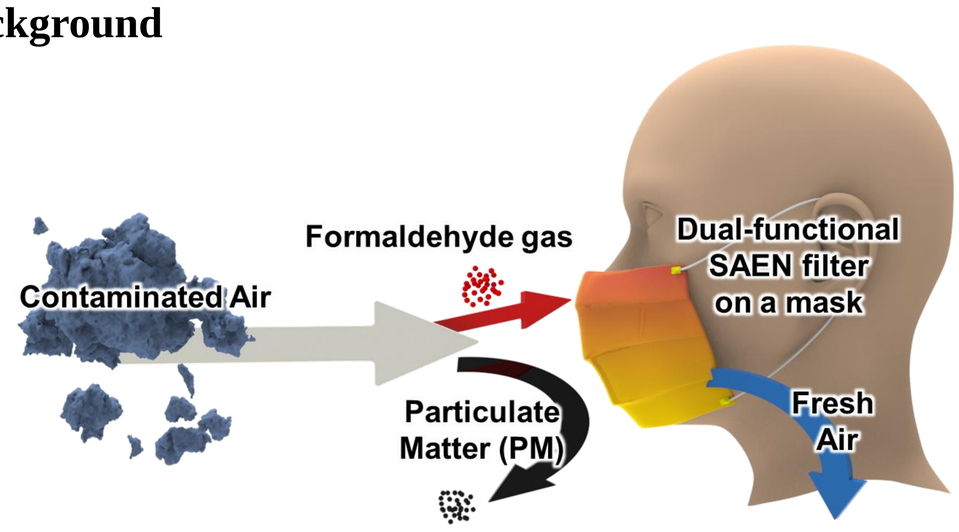


Figure. 1. Dual-functional self-assembled electrospun nanofiber filters for PM removal and formaldehyde sensing simultaneously

► Nanofiber mat has been utilized for air filtration due to its micro/nano-sized porous structure. However, the deposition of nanofibers having a non-uniform thickness occurred when electrospinning was performed on a non-conductive mesh collector with a protruded or curved region. The non-uniform thickness of nanofibers reduced the filtration efficiency of filter. Therefore, an another electrospinning process or additional process was required for efficient air filtration.

Objective

►This study is focused on the direct fabrication of nanofiber mats with the self-assembled structure and uniform thickness by electrolyte-assisted electrospinning(ELES) for highly efficient air filtration and formaldehyde gas detection.

Approach

►We directly fabricated a self-assembled and uniform thicken nanofiber mat on non-conductive cotton fabric. The self-assembled structure of the nanofiber mat was conformally deposited on the collector and captures more particulate matter (PM) than the nanofiber mat fabricated with the same amount of electrospinning solutions by the conventional electrospinning. Also, formaldehyde-sensitive solution was applied as a electrolyte solution for nanofiber filters, thereby, colorimetric formaldehyde sensing was conducted simultaneously with PM removal.

Experimental Setup & Experiment

Electrospinning preparation & perform

► Electrospinning was conducted on non-conductive cotton fabric meshes. Under the conditions shown in Table, the solutions were fed with 23-gauge needle tip and the cotton fabric was located 20cm below the tip. Nanofiber mat fabricated was directly deposited on the cotton fabric by the conventional electrospinning process and ELES process.

Name	Solvent (grade, %, ratio)	Solute	Feed rate (mL)	Remark
PCL/Gel	2,2,2 – Trifluoroethanol (99.0%, TFE)	Polycaprolactone (M_n 80,000, 5 w/v%) Gelatin Type B	0.4 / 20kV	Added 10μL Acetic acid (9 9.7%)
PS	N,N-Dimethylformamide (99.8%, DMF)	Polystyrene (M_w ~280,000)	0.5 / 20kV	Added 0.01 w/w% Tetrabutylammonium bromide
Nylon	Formic acid (98%) : Chloroform(99.5 %) = 5 : 5	Nylon 6 (polycaprolactam)	0.2 / 20kV	
PVDF	DMF : Acetone (99.7%) = 7 : 3	Poly(vinylidene fluoride) (M_w ~275,000)	0.5 / 20kV	Stirred over 60 °C

System for evaluating the filtration efficiency of a nanofiber mat

►A filter evaluation system was constructed as shown in Figure 2A to measure the environmental purification ability of nanofiber mats. The diluted fine dusts move to the left by the pressure of the fan motor and are filtered by a filter media. The filtration efficiency of two filter medias (KF94 mask, cotton fabric mask) measured through the filter evaluation system is shown in Figure 2B. As a result, it was confirmed that the KF94 mask showed 98.4% filtration efficiency, which is 2.78 times higher than that of the cotton mask, and the standard deviation was lowered to 1/3 level. This result is the same as the previously known filtration efficiency value of the mask, and through this, it was confirmed that the system for measuring the environmental purification ability of the nanofiber mat produced in this study was stably operated.

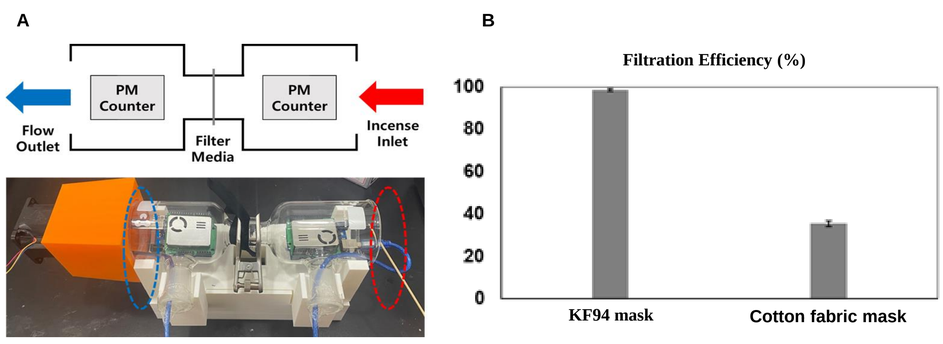
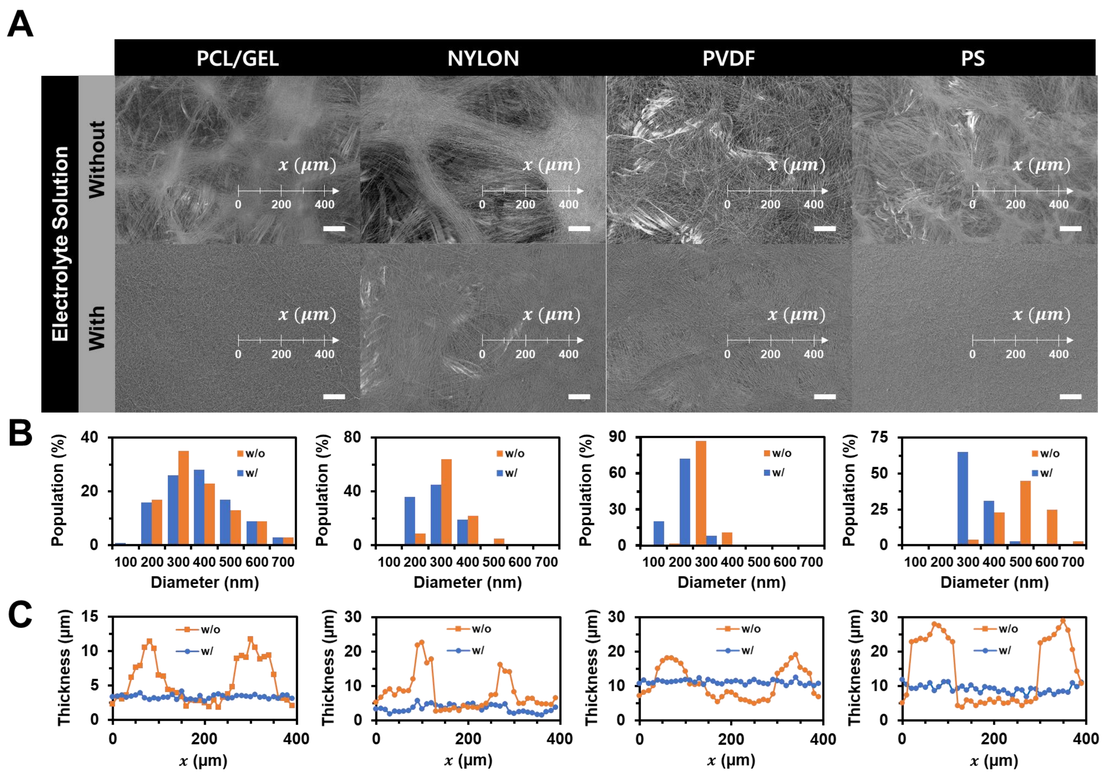


Figure 2. (A) Schematic (top) and device image (bottom) of filtration testing system. (B) Filtration efficiency of KF94 mask and cotton fabric mask testing by filtration system.

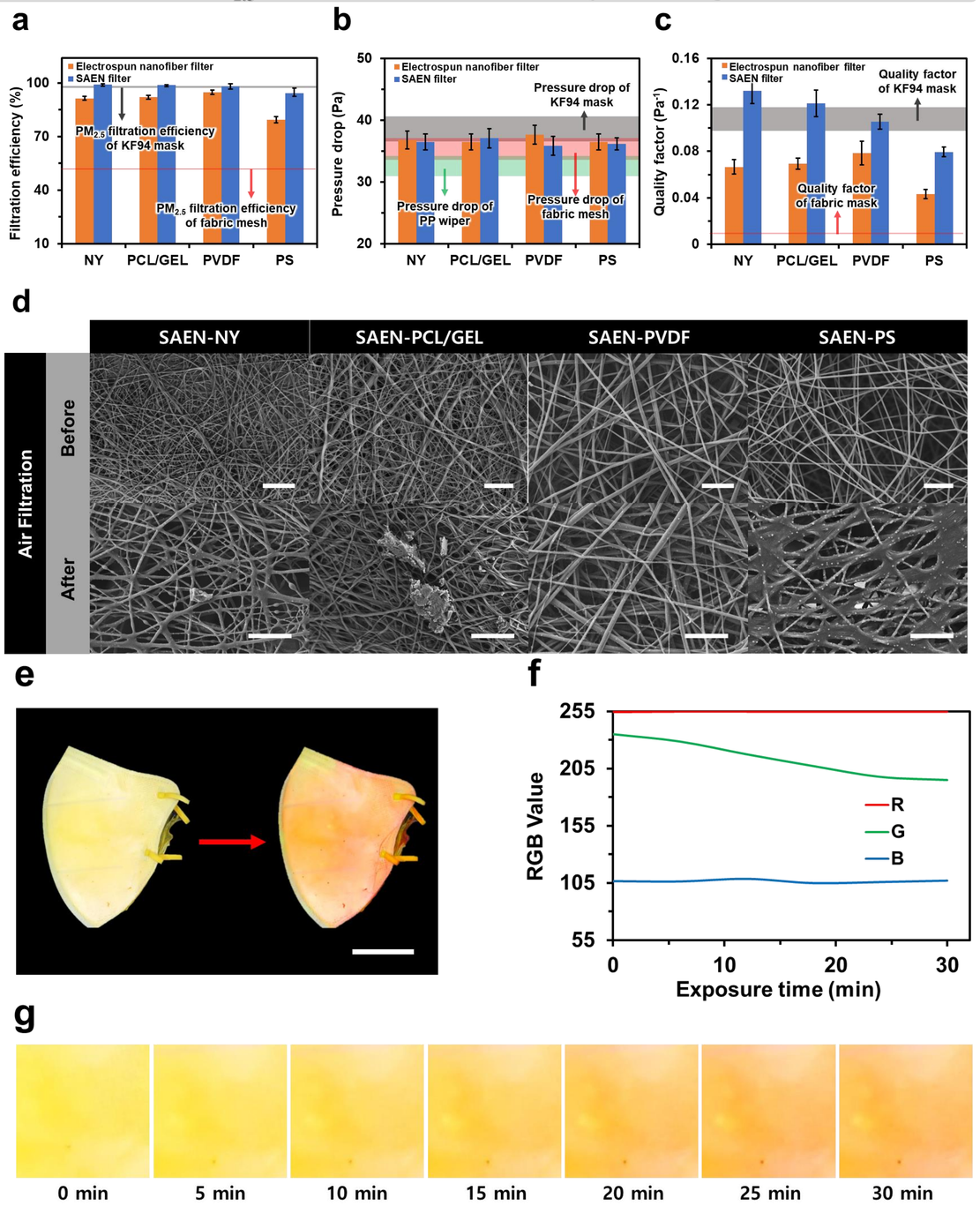
Results and Discussion

Self-assembled Structure and Uniform Thickness of Nanofiber Mat



►Directly deposited nanofiber with and without the electrolyte solution are shown in A. In Figure B, diameter of nanofibers were slightly decreased, but distribution tendency were maintained.

$PM_{2.5}$ Filtration Test & Formaldehyde Sensing Test



►$PM_{2.5}$ filtration results were indicated with SEM image in Fig. a to d. Self-assembled structures were successfully fabricated, and among them, NY and PCL/GEL self-assembled nanofiber filters were applied to capture PM efficiently compared to KF94 mask.

►Also, self-assembled electrospun nanofiber filters were fabricated with formaldehyde-sensitive solution with ELES and detect formaldehyde gas, as shown in Fig. e to g.

Conclusions

►We demonstrated the direct fabrication of nanofiber mats with the self-assembled structure and uniform thickness. Through the nanofiber mat with the self-assembled structure, we aimed to improve air filtration efficiency and detect formaldehyde gas simultaneously. It is expected to apply for the fabrication process of efficient nanofiber mats for dual functional air filters.