Preparation of electrospun PVA@Ls@BAC@PDMS composite nanofibrous air filtration membrane with high efficiency removal for PM2.5 and excellent heat resistance

Yi Wang[1] | Yu Miao[1] | Yuxin Cai [1] | Enfu Wang[1] | YiPeng Liang[1] | Jinhuan Zhong[1] | Wenbiao Zhang[1] | Jingda Huang[1,2]

1College of Chemistry and Materials Engineering, Zhejiang A&F University,Hangzhou, China

2College of Biosystems Engineering and Food Science, Zhejiang University,Hangzhou, China

Abstract

Development of water-soluble polymer air filtration materials attracts considerable attentions due to their environmentally friendly performance and high efficiency, but the balance of mechanical strength, efficiency and pressure drop still is a severe challenge. Focusing on this issue, polyvinyl alcohol (PVA),bamboo activated carbon (BAC) and sodium lignosulfonate (Ls) were combined to construct an electrospinning system with two filtration functions. In the PVA@Ls@BAC system, the 3D network constructed by the electrospun PVA based nanofibrous could effectively intercept PM2.5, and the introduced Ls enhanced the mechanical strength of PVA nanofibrous due to its good rigidity. In addition, the added negatively charged BAC facilitated the electrostatic adsorption of PM2.5 while also improved the heat resistance of the system.Moreover, polydimethylsiloxane (PDMS) was introduced to enhance the water resistance of the system. The resulting electrospun PVA@Ls@BAC@PDMS composite nanofibrous air filtration membrane exhibited excellent air filtration performance (98.67%), water repellency (123.7% of WCA), and reusable performance, as well as having good mechanical property and the tensile fracture strain reaching 112%. Because of its good performance and simple preparation process, the electrospun PVA@Ls@BAC@PDMS composite nanofibrous air filtration membrane has great application space.

Forming and working mechanism of nanofibrous air filtration membrane

Forming mechanism of the PVA@Ls@BAC@PDMS composite nanofibrous air filtration membrane was shown in Figure 1A. BAC, Ls and PDMS were added to the PVA solution and then conducted for electrospun to prepare the nanofibrous air filtration membrane. In the system, lignin molecule is of good rigidity and has a certain of hydroxyl groups,which is benefited to form hydrogen bond with PVA,enhancing the strength of electrospun nanofibrous. In addition, the introduced nano BAC could effectively prevent nanofibrous bonding.Further,the surface of BAC is rich in oxygen-containing groups such as carboxyl groups, and the oxygen-containing functional groups of carboxyl groups were deprotonated under alkaline conditions, carrying negative charges, which was benefited to the capture of PM2.5 with positive charge by electrostatic adsorption.The addition of PDMS made the system stably hydrophobic.

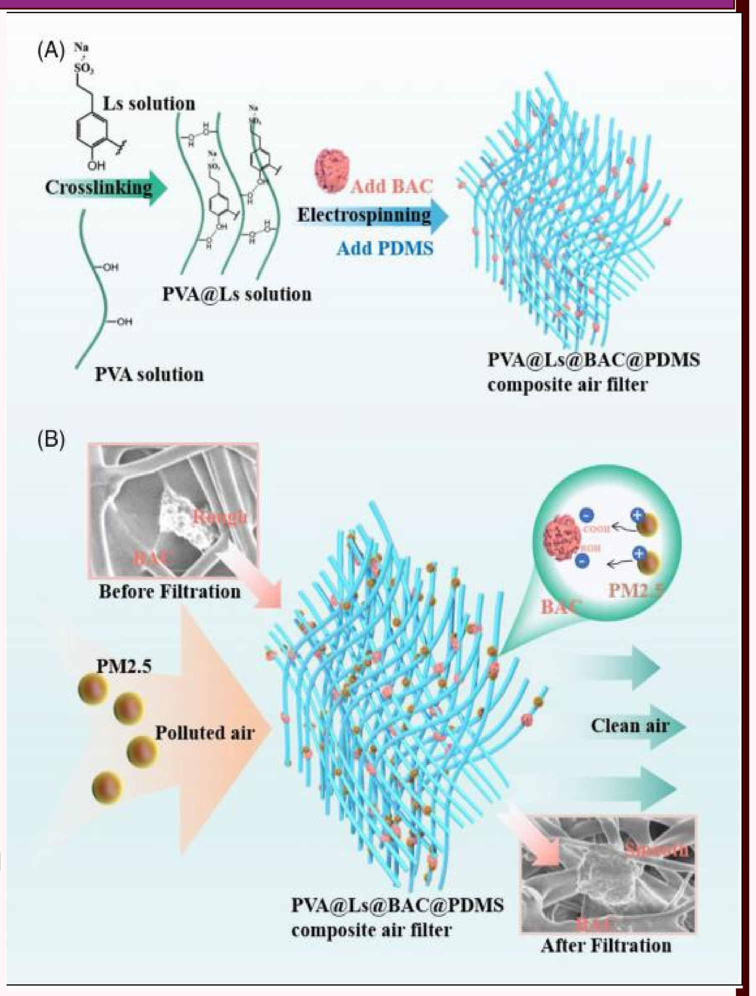


Fig. 1.(A) Forming mechanism and (B) PM2.5 filtration principle of PVA@Ls@BAC@PDMS composite nanofibrous air filtration membrane.

Results - Filtration capacity

- The PVA/BAC/Ls (9:2.5:2) one had the best filtration efficiency of 99.36 %.
- The quality factor (Qf) of the PVA/BAC/Ls (9:2.5:2)was reached 0.140 Pa^{-1}, showing exceptional comprehensive filtration performance.

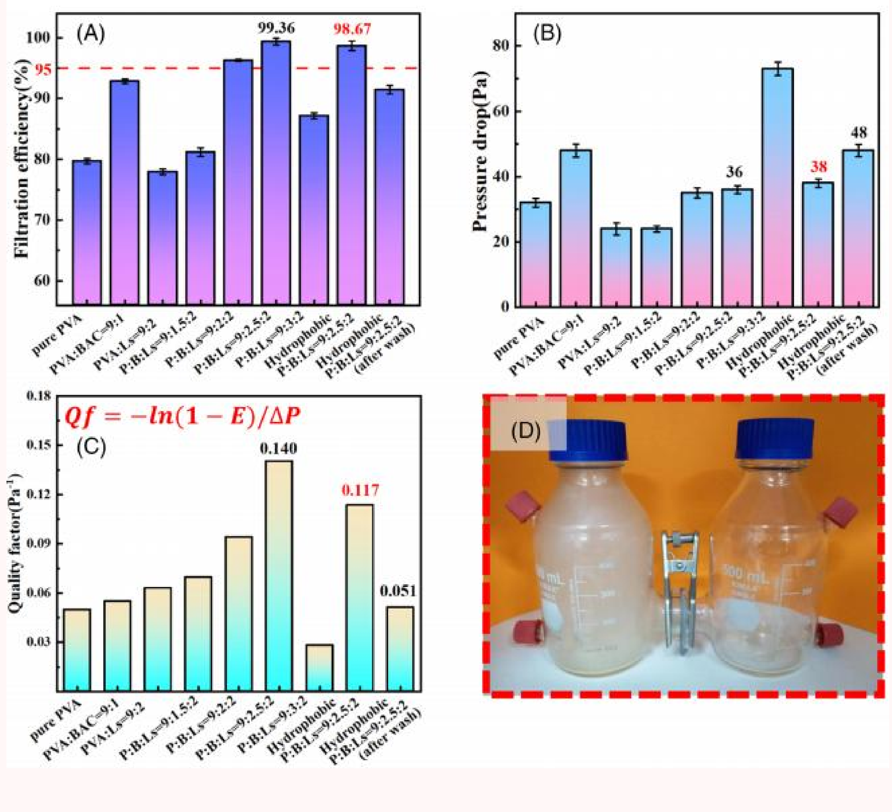
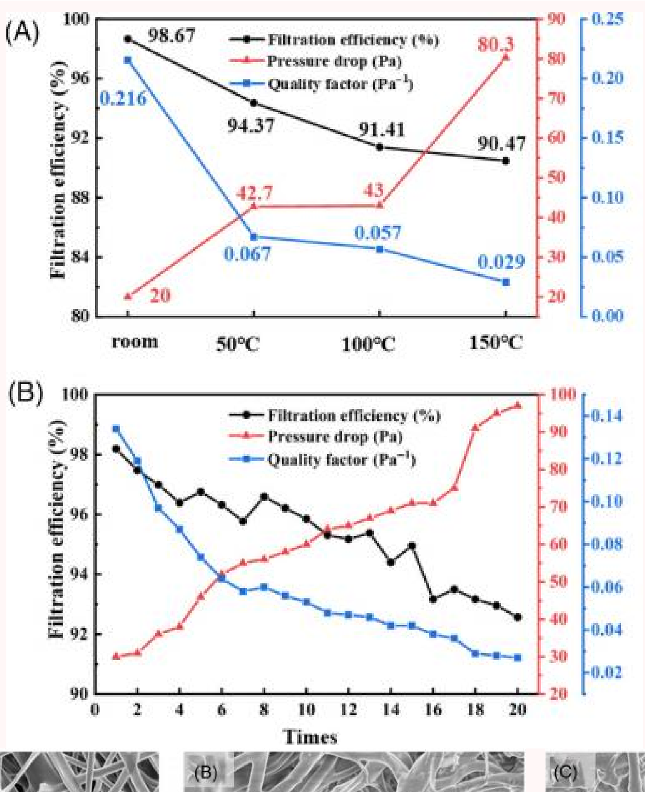


Fig. 2. (A) Filtration efficiency, (B) pressure drop and (C) corresponding quality factor of different air filters for PM2.5 under gas velocity of 5 cm/s; (D) picture for barrier of sample to PM2.5;

Results - Regeneration

- The nanofibrous air filtration membrane had excellent stability in the high temperature filtration process.
- The hydrophobic PVA/BAC/Ls one still maintained high filtration performance (>91%) after after 20 times of filtration (Fig. 3b).
- After water washing, most particles on the surface of the sheet were removed and the pores were unblocked (Fig. 4a-c).



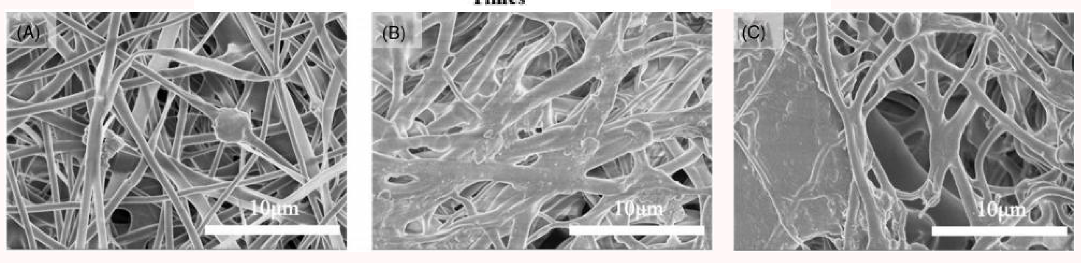


Fig. 3. Filtration efficiency, pressure drop and quality factor of PVA@Ls@ BAC@PDMS composite nanofibrous air filtration membrane
(A) at room temperature, 50, 100,and 150 °C, (B) after 20 times of filtration;
Fig. 4.Scanning electron microscopy images of PVA@Ls@BAC@PDMS composite nanofibrous air filtration membrane (A) before and (B) after filtration, (C) after water washing

Conclusions

The PVA@Ls@BAC@PDMS composite nanofibrous air filtration membrane with multi-filtration functions could be constructed by the introduction of Ls, BAC and PDMS to PVA, followed by electrospun. Ls could effectively improve the mechanical strength, BAC improving the porosity and increasing electrostatic adsorption, and PDMS enhancing water resistance to the system. The resulting PVA@Ls@BAC@PDMS composite nanofibrous air filtration membrane exhibited high efficiency removal for PM2.5, only the pressure drop of 48 Pa. Its tensile fracture strain reached 112%,which was significantly improved compared to the pure PVA one. Moreover, even after 20 times of filtration, the filtration efficiency remained above 91%. Due to its excellent performance and environmental friendliness,the composite nanofibrous air filtration membrane has great development potential.

Acknowledgements

Project funded by China Postdoctoral Science Foundation(No. 2021M692806), Natural Science Foundation of Zhejiang Province (No. LY21C160002), Scientific Research Development Foundation of Zhejiang A&F University (No. 2018FR054).

浙江农林大学
ZHEJIANG A&F UNIVERSITY