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Supporting Information

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Experimental and Numerical Investigation of Slip Effect on Nanofiber Filter Performance at Low Pressures

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Experimental and Numerical Investigation of Slip Effect on Nanofiber Filter Performance at Low Pressures

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This "supporting information" includes **Text. S1**, **Text. S2**, and **Fig. S**1 to **S**3.

Text S1. **Semi-empirical equations for predicting particle filtration efficiency**

For the filters where the flow behavior shows the slip flow regime character, the semi-empirical equations for predicting the particle filtration efficiency can be summarized as follows,

$$P = \exp\left(\frac{-4\alpha E_{\Sigma} t}{\pi(1-\alpha)d_{\mathrm{f}}}\right) \tag{1}$$

$$E_{\Sigma} = E_{\mathrm{R}} + E_{\mathrm{D}} + E_{\mathrm{I}} + E_{\mathrm{DR}} \tag{2}$$

$$E_{\mathrm{R}} = ((1-\alpha)/Ku)(R^2/(1+R))(1+1.996Kn/R) \tag{3}$$

$$E_{\mathrm{D}} = 1.6((1-\alpha)/Ku)^{1/3} Pe^{-2/3}(1+0.388Ku^{-1}Pe^{1/3}(1-\alpha)Kn) \tag{4}$$

$$E_{\mathrm{I}} = Stk^3/(Stk^3 + 0.77Stk^2 + 0.22) \tag{5}$$

$$E_{DR} = 1.24R^{2/3}/(KuPe)^{1/2} \tag{6}$$

For the filters where the flow behavior shows the transition flow regime character, the semi-empirical equations for predicting the particle filtration efficiency can be summarized as follows,

$$E_{\Sigma} = E_{\mathrm{R}} + E_{\mathrm{D}} + E_{\mathrm{I}} \tag{7}$$

$$E_{\mathrm{R}} = 0.77((1-\alpha)/Ku)\,(R^2/(1+R))\,(1+0.24Kn/R + 0.21Kn/R^2) \tag{8}$$

$$E_{\mathrm{D}} = (2.28Ku^{-1/3}Pe^{-2/3} - 0.08Pe^{-1})\,(1-0.67Ku^{-1/3}Pe^{1/3}Kn) \tag{9}$$

$$E_{\mathrm{I}} = Stk^3/(Stk^3 + 0.77Stk^2 + 0.22) \tag{10}$$

Text S2. **Dependence test of different voxel sizes**

The voxel size dependence was studied as depicted in **Fig. S3**. The *x*-axis represents the ratio of fiber diameter to voxel size, denoted as d_f/l_{voxel}, while the y-axis shows the corresponding pressure drop or filtration efficiency. For the MF-2 filter, composed of microfibers (d_f = 3.9 μm), the simulated pressure drops become stable when the fiber diameter to voxel size ratio is around 13 (**Fig. S3**a1). In addition to the pressure drop, the effect of voxel size on simulated filtration efficiency was also studied (**Fig. S3**a2). Filtration efficiency, particularly for particle sizes larger than 100 nm, decreases as the voxel size decreases, and becomes stable when d_f/l_{voxel} is around 13. As the voxel size decreases, the resolution of the flow field improves, and the particle displacement at each step is reduced, enhancing the accuracy of tracking particle movement. Therefore, a ratio of 13 was employed for the following simulations, balancing accuracy and computational cost. For the NF-2 filter, composed of nanofibers (d_f = 0.138 μm), the fiber diameter to voxel size ratio was determined as 4, at which the simulated pressure drop and filtration efficiency became stable.

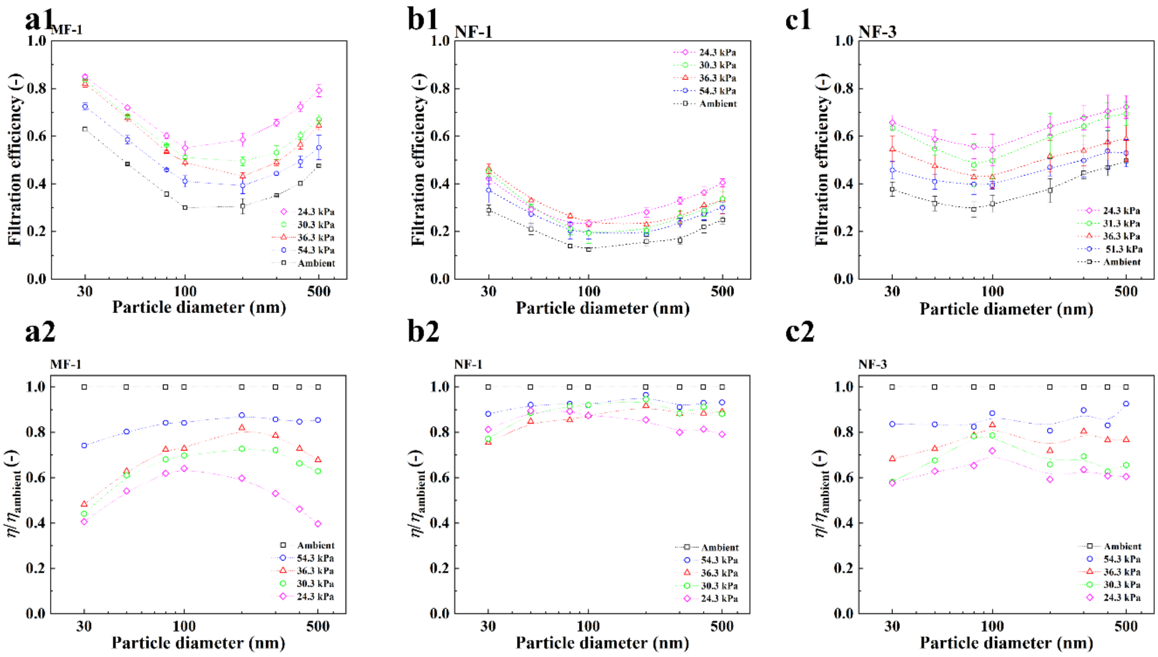

Fig. S1. The tested filtration efficiency against particle diameters of filter a1) MF-1, b1) NF-1, and c1) NF-3. The normalized particle penetrations against particle diameters of filter a2) MF-1, b2) NF-1, and c2) NF-3

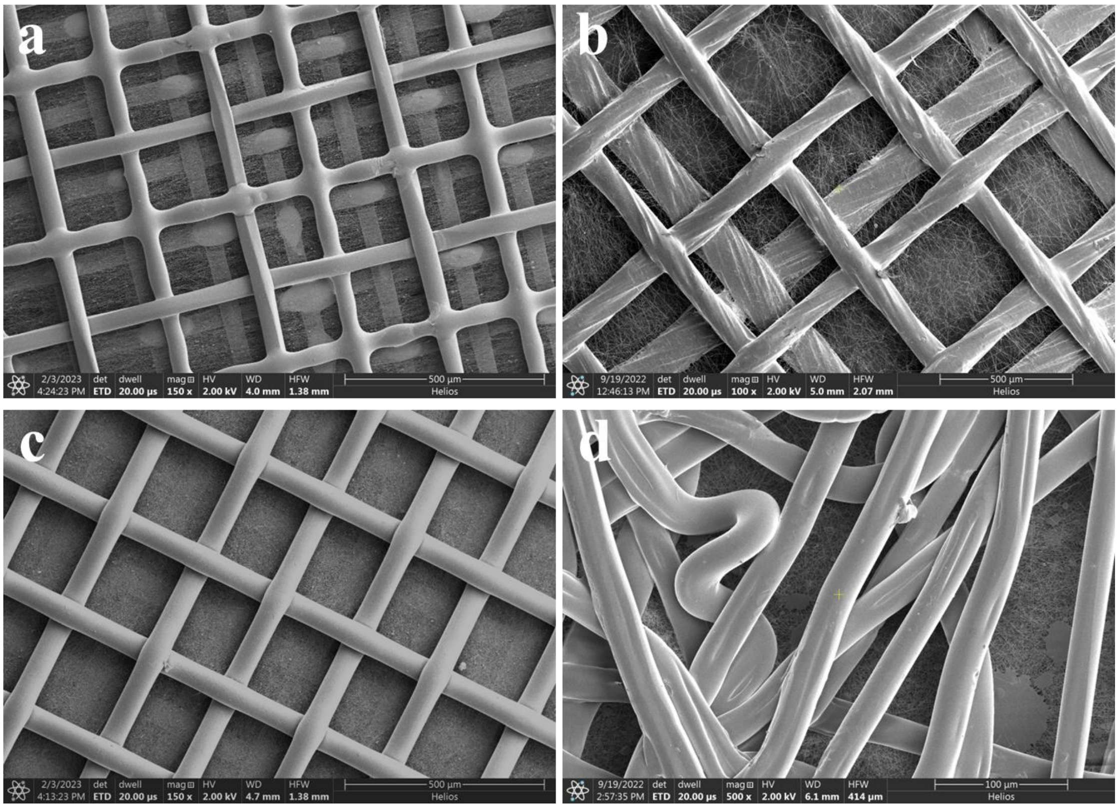

Fig. S2 Nanofiber filter media a) NF-1, b) NF-2, c) NF-3 with a nanofiber layer sandwiched by two micro-meshes. (d) NF-4 with a nanofiber layer coated on the substrate

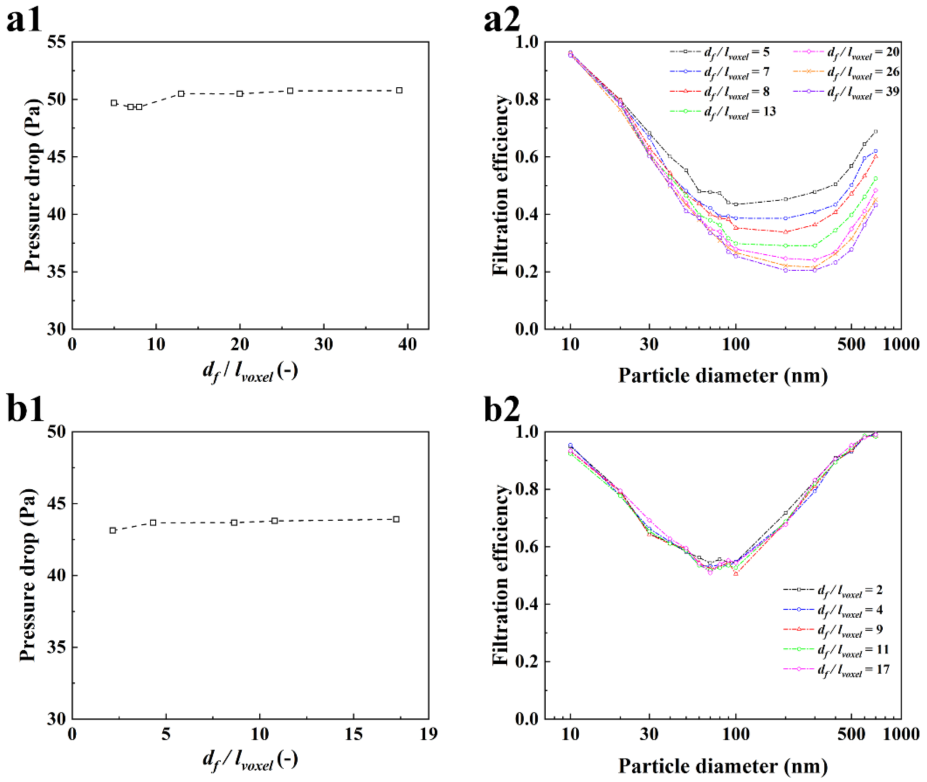

Fig. S3. Dependence test of different voxel sizes. Simulated a1) pressure drop and a2) filtration efficiency of filter MF-2 with different voxel sizes. Simulated b1) pressure drop and b2) filtration efficiency of filter NF-2 with different voxel sizes