Supporting information for

Multifunctional polyethylene (PE)/ polypropylene (PP) bicomponent fiber
filter with anchored nanocrystalline MnO₂ for effective air purification

Zijian Dai a, Jiafei Su b, Xiaoming Zhu a, Kangli Xu a, Jie, Zhu a, Chen Huang a, Qinfei Ke, *, a, b

a Key Laboratory of Textile Science & Technology (College of Textiles, Donghua University), Ministry of Education, Shanghai 201620, P. R. China. E-mail address: kqf@shnu.edu.cn

b Environmental Materials Research Center, Shanghai Normal University, Shanghai 200234, P. R. China
Fig. S1 Technological manufacturing process of MnO$_2$/PE/PP multifunctional filters.

Fig. S2 Schematic diagram of needle-plane electrode system for corona charging process: 1. Metal needle, 2. Swatch, 3. Copper holder, 4. High voltage power supplier.
Synthesis of $\alpha$-MnO$_2$, $\delta$-MnO$_2$

To synthesize $\alpha$-MnO$_2$ via co-precipitation method, 3.16 g of KMnO$_4$ and 4.53 g of MnSO$_4$ were added in 50 mL of deionized water and stirred at 90 °C, respectively. Afterward, the KMnO$_4$ and MnSO$_4$ solutions were added dropwise into 50 mL of deionized water, respectively. The as-prepared solution was then stirred and reacted at 90 °C for 2 h. Finally, the MnO$_2$ powders were washed, centrifuged and dried at 80 °C for 12 h. For $\delta$-MnO$_2$, 3.16 g of KMnO$_4$ and 2.26 g of MnSO$_4$ were reacted at 80 °C for 2 h.

Adsorption and Catalytic Activity Test

A polytetrafluoroethylene layer stainless steel reactor (0.5 L) was used, at the bottom of which was placed a quartz Petri dish with MnO$_2$/PE/PP swatch inside. After putting the dish into the reactor, 300 ppm of HCHO was injected into the reactor. After stabilizing the concentration of HCHO to 150 ppm, the cover of the dish was removed to start the adsorption and catalytic reaction of HCHO. HCHO, CO$_2$, CO and water vapor were recorded online during test at 30 °C. The yield of CO$_2$ ($\Delta$CO$_2$) and the concentration variation of HCHO were calculated to analyze the HCHO removal ratio.

![XRD patterns](image)

Fig. S3 XRD patterns of $\alpha$-MnO$_2$-1, $\alpha$-MnO$_2$-2, $\delta$-MnO$_2$-1, and $\delta$-MnO$_2$-2.
**Detailed operating process of O$_2$-TPD**

The as-prepared samples were first transferred to U-type quartz tube and pretreated by 20% O$_2$/He mixed gas. The samples were heated from room temperature to 300 °C at a rate of 10 °C/min and were soaked for 30 min. After that, the samples were cooled down to 50 °C at flowing stream of 20% O$_2$/He (30 mL/min), and then pure He gas was introduced to flow through the sample for 30 min. Finally, the temperature was elevated from 50 °C to 900 °C at He stream (30 mL/min).
Fig. S5 XRD patterns of $\delta$-MnO$_2$-2 (treated at 135 °C for 30 min), PE/PP bicomponent fiber and MnO$_2$/PE/PP fiber mat.

Fig. S6 Optical images of MnO$_2$/PE/PP nonwovens with (a) 0%, (b) 5%, (c) 8% and (d) 11% of $\delta$-MnO$_2$-2.
Fig. S7 TG-DTA results for MnO$_2$/PE/PP swatches with different supply air pressure: (a) 0 Pa, (b) 0.1 Pa, (c) 0.2 Pa, and (d) 0.3 Pa.

Table S1 Filtration performance of selected materials for air filtration

<table>
<thead>
<tr>
<th>Filters</th>
<th>Basic weight (g·m$^{-2}$)</th>
<th>Filtration efficiency (%)$^a$</th>
<th>Pressure drop (Pa)</th>
<th>QF (Pa$^{-1}$)$^b$</th>
<th>Ref</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spunbond PP/PE</td>
<td>120</td>
<td>88.61%±1.96%</td>
<td>22.56±2.24 Pa</td>
<td>0.096±0.0065</td>
<td>1</td>
</tr>
<tr>
<td>Meltblown PP/PET</td>
<td>35</td>
<td>67.47</td>
<td>13.12</td>
<td>0.086</td>
<td>2</td>
</tr>
<tr>
<td>Sundbond PET/PA6</td>
<td>170</td>
<td>69.00</td>
<td>100</td>
<td>0.012</td>
<td>3</td>
</tr>
<tr>
<td>Sundbond PA6/PE</td>
<td>106</td>
<td>60.70</td>
<td>27.44</td>
<td>0.034</td>
<td>4</td>
</tr>
<tr>
<td>Meltblown nano PP</td>
<td>40</td>
<td>99.98</td>
<td>280</td>
<td>0.030</td>
<td>5</td>
</tr>
<tr>
<td>Electrospun PA-6</td>
<td>0.9</td>
<td>99.99</td>
<td>95</td>
<td>0.11</td>
<td>6</td>
</tr>
<tr>
<td>Electrospun PSU/PU</td>
<td>6.79</td>
<td>99.94</td>
<td>184.6</td>
<td>0.040</td>
<td>7</td>
</tr>
<tr>
<td>Through-air bonded</td>
<td>180</td>
<td>71.73</td>
<td>6.02</td>
<td>0.222</td>
<td>This work</td>
</tr>
<tr>
<td>MnO$_2$/PE/PP</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

$^a$ The filtration efficiency was measured using aerosols with an average diameter of 0.3 μm. The face velocity was around of 5.33 cm·s$^{-1}$.

$^b$ The quality factor (QF) was calculated by the following formula: \( QF = -\ln \left(1 - \eta \right)/\Delta p \), where \( \eta \) and \( \Delta p \) represent filtration efficiency and pressure drop, respectively.
Fig. S8 Representative filtration efficiency and pressure drop of MnO₂/PE/PP nonwovens with 0%, 5%, 8% and 11% of δ-MnO₂-2 after 35 days decay. (a) before corona and (b) after corona charge.

Notes and references