Morphology-controlled green synthesis of Tellurium Nanostructures
and application of Te/MXene hybrid structure

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Figure S1. Experimental method and operation process of synthesizing Te NWs
**Figure S2.** Wide-range XPS spectra of Te nanotube prepared at 90 °C. Obvious Te 3d peaks are demonstrated by the XPS spectra of Te nanotubes, similar to those of Te nanowires.

**Figure S3.** High-resolution XPS spectrum of the C 1s peak for Te/C nanocables.
Figure S4. (a) OM image of the synthesized tellurene on SiO$_2$ substrate. Scale bar, 30 μm. (b) SEM image of synthesized tellurene. Scale bar, 5 μm. (c) Raman spectra of the synthesized tellurene.

The images in Figure S4 exhibit the characterizations of the synthesized 2D tellurene. Figure S4a is the OM image of tellurene on a SiO$_2$ substrate, in which various uniform 2D nanosheets were observed. The SEM image in Figure S4b confirms the lateral dimension of tellurene ~10 μm. Raman spectroscopy was used to explore the crystal structure of the obtained tellurene, and the spectra are shown in Figure S4c. Three active modes located at 92, 121, and 141 cm$^{-1}$ are donated as the E1, A1, and E2 vibration modes, respectively, consistent with the reported works.\textsuperscript{1-3}

Figure S5. Transfer curve of the synthesized Te NWs film. $V_d$=0.1 V.

For the transfer curve in Figure S5, the drain current slightly changed with the increase of gate voltage from -20 V to 20 V, and high drain current could be obtained at low drain voltage, indicating the high metallic conductivity of Te NWs. As reported, high junction resistance exists between individuals in nanotube films\textsuperscript{4} and the poorly conductive amorphous carbon shells of nanocables decrease the conductivity of Te nanocable film\textsuperscript{5}, so Te NWs were employed for the application of transparent conductive electrodes in this work.
The investigations of the synthesized Ti$_3$C$_2$Tx flakes are shown in Figure S6. The OM image in Figure S6a and SEM image in Figure S6b indicate the exfoliated large-area and thin Ti$_3$C$_2$Tx flakes. The XRD pattern in Figure S6c further confirms the high quality of the achieved Ti$_3$C$_2$Tx flakes, in which a weak peak at 39° is observed.\textsuperscript{6,7}

Figure S7 is the schematic of fabricating Te NWs/MXene hybrid structure. Firstly, the substrate was cleaned with ethanol (C$_2$H$_5$OH) and deionized (DI) water. Then, in sequence, Te NWs and MXene solutions were spray-coated on the prepared substrate.
Figure S8. Sheet resistances and transmittances of Te and Te NWs/MXene hybrid structures with different solution concentrations of Te NWs.

The sheet resistances and transmittances at 550 nm of pure Te and Te NWs/MXene hybrid structures were measured and summarized in Fig. S8. With the spray-coating of the MXene layer, significant performance enhancements were demonstrated by Te/MXene hybrid structures with lower sheet resistances and similar transmittances. When the solution concentration of Te NWs is 10 mg/mL, the sheet resistance of Te film is difficult to measure, so 20 mg/mL is the minimum concentration investigated in this work.
Figure S9. Sheet resistances and transmittances of Te NWs/MXene hybrid structure with different solution concentrations of MXene. Te NWs/MXene1: Te NWs/MXene hybrid structure with one layer of MXene. Te NWs/MXene2: Te NWs/MXene hybrid structure with two layers of MXene.

Table S1 A comparison of various transparent conductive electrodes.

<table>
<thead>
<tr>
<th>Material</th>
<th>Method</th>
<th>Sheet resistance (Ω/sq)</th>
<th>Transmittance (%)</th>
<th>Refs.</th>
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<tbody>
<tr>
<td>Ti$_3$C$_2$Tx in water</td>
<td>Spray-coating</td>
<td>1300</td>
<td>68</td>
<td>8</td>
</tr>
<tr>
<td>Ti$_3$C$_2$Tx in ethanol</td>
<td>Spray-coating</td>
<td>3500</td>
<td>58</td>
<td>8</td>
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<td>rGO</td>
<td>Filtration</td>
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<td>59</td>
<td>9</td>
</tr>
<tr>
<td>graphene</td>
<td>CVD growth</td>
<td>280</td>
<td>80</td>
<td>10</td>
</tr>
<tr>
<td>Te/MXene</td>
<td>Spray-coating</td>
<td>156</td>
<td>70</td>
<td>This work</td>
</tr>
</tbody>
</table>

rGO: reduced graphene oxide.

Various transparent conductive electrodes based on nanomaterials are summarized in Table 1. Compared with pure Ti$_3$C$_2$Tx TCEs, the Te/MXene hybrid structure shows a lower sheet resistance with a higher transmittance, which is supposed to be attributed to (1) the Te NWs distributed across the MXene flakes act as conductive bridges and reduce the contact resistance. (2) the Te/MXene hybrid structure could be a resistivity in parallel problems, the total resistance of Te/MXene TCE is lower than every individual component in the hybrid conductive structures. Therefore, compared to pure MXene film, Te/MXene hybrid TCE demonstrates a better performance.
References
6. H. Y. Shunlong Zhang, Pengfei Huang, Jianli Wang, Zhao Zhang, Tiantian Yang, and Wei-Qiang Han, ACS nano, 2020, 14, 17665-17674.