Electronic supplementary information (ESI)

# Oxidation-driven SnS conversion to two-dimensional porous $SnO_2$ flakes towards $NO_2$ gas sensing

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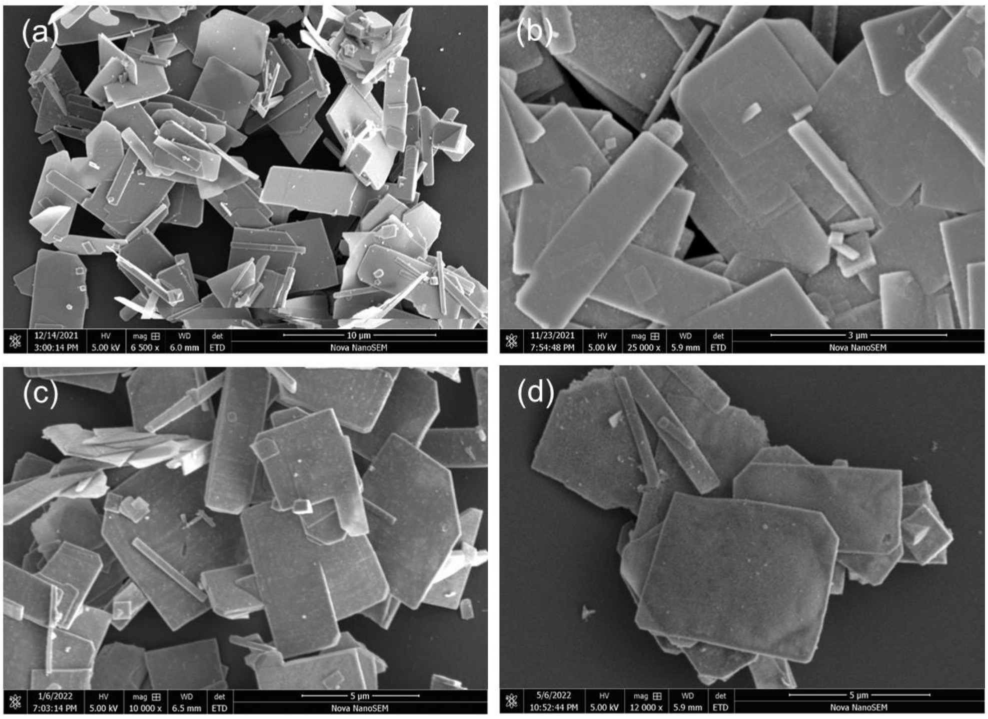


**Fig. S1** SEM images of (a,b) SnS flakes (as-prepared) and (c,d) SnS-$SnS_2$-$SnO_2$ flakes (400 °C).

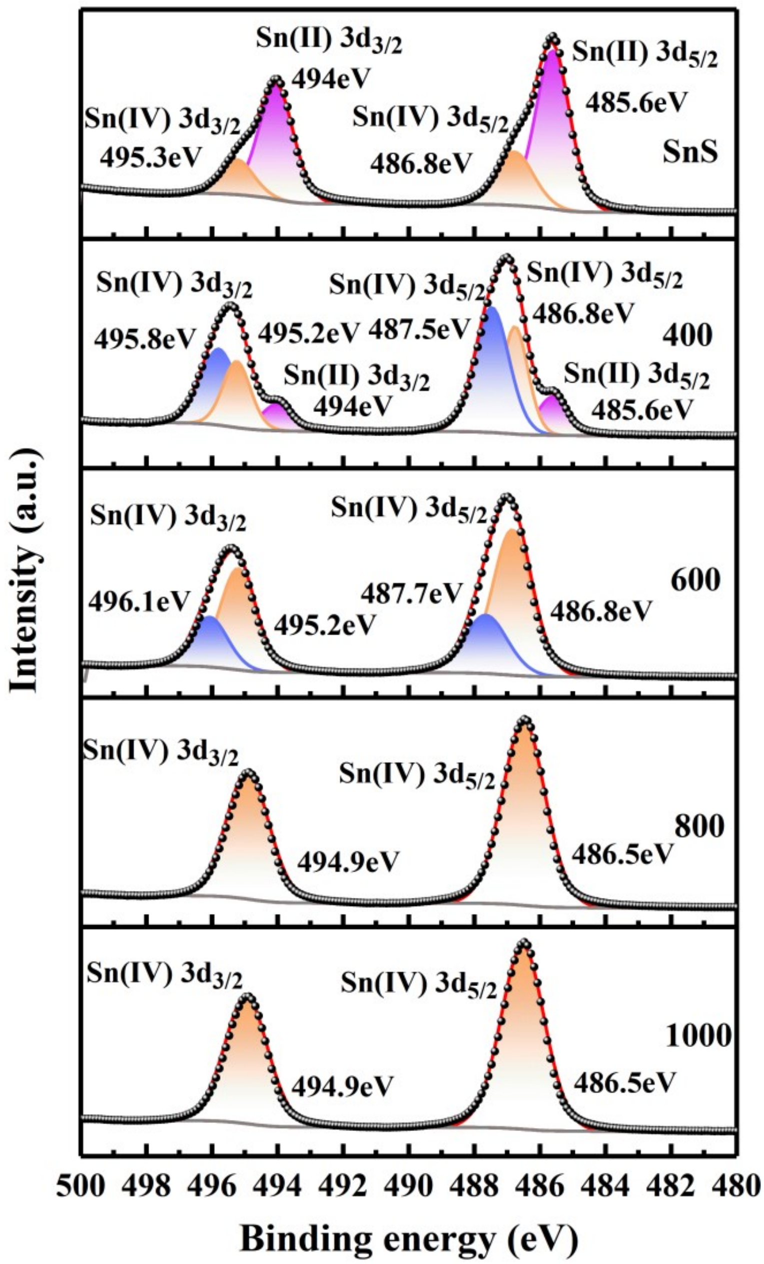


**Fig. S2** Sn 3d core-level XPS spectra of as-prepared SnS flakes and the products obtained at different oxidation temperatures (°C) as labeled. The binding energies for the different chemical states of Sn 3d from various samples are detailed in Table S1.

**Table S1** The binding energies (BEs) for different oxidation states of Sn 3d from various samples.

<table>
<tr><th>Materials</th><th colspan="4">Binding energy</th></tr>
<tr><td>SnS</td><td colspan="2">[a]Sn-O (SnO)<br>Sn(II)$3d_{3/2}$: 495.3 eV<br>Sn(II)$3d_{5/2}$: 486.8 eV</td><td colspan="2">SnS-$Sn^{2+}$<br>Sn(II)$3d_{3/2}$: 494.0 eV<br>Sn(II)$3d_{5/2}$: 485.6 eV</td></tr>
<tr><td>SnS-$SnS_2$-$SnO_2$<br>(400 °C)</td><td>[b]$SnS_2$-$Sn^{4+}$<br>Sn(IV)$3d_{3/2}$: 495.8 eV<br>Sn(IV)$3d_{5/2}$: 487.5 eV</td><td colspan="2">[b]$SnO_2$-$Sn^{4+}$<br>Sn(IV)$3d_{3/2}$: 495.2 eV<br>Sn(IV)$3d_{5/2}$: 486.8 eV</td><td>SnS-$Sn^{2+}$<br>Sn(II)$3d_{3/2}$: 494.0 eV<br>Sn(II)$3d_{5/2}$: 485.6 eV</td></tr>
<tr><td>$SnS_2$-$SnO_2$<br>(600 °C)</td><td colspan="2">[b]$SnS_2$-$Sn^{4+}$<br>Sn(IV)$3d_{3/2}$: 496.1 eV<br>Sn(IV)$3d_{5/2}$: 487.7 eV</td><td colspan="2">[b]$SnO_2$-$Sn^{4+}$<br>Sn(IV)$3d_{3/2}$: 495.2 eV<br>Sn(IV)$3d_{5/2}$: 486.8 eV</td></tr>
<tr><td>$SnO_2$<br>(800 °C)</td><td colspan="4">[b]$SnO_2$-$Sn^{4+}$<br>Sn(IV)$3d_{3/2}$: 494.9 eV<br>Sn(IV)$3d_{5/2}$: 486.5 eV</td></tr>
<tr><td>$SnO_2$<br>(800 °C)</td><td colspan="4">[b]$SnO_2$-$Sn^{4+}$<br>Sn(IV)$3d_{3/2}$: 494.9 eV<br>Sn(IV)$3d_{5/2}$: 486.5 eV</td></tr>
</table>

***Notes:*** [a]The shoulder peaks are usually considered from the surface oxidation of SnS, namely, SnO, which is found to have similar BEs to that of Sn(IV) of $SnS_2$ (refer to: *Chem. Mater.* 2016, ***28***, 3718−3726; *Phys. Rev. Mater.* 2020, ***4***, 074602).

[b]The BEs of $SnS_2$ are higher than that of $SnO_2$. The reason may be due to the existence of oxygen vacancies that reduce the oxidation state of $Sn^{4+}$ to $Sn^{(4-x)+}$ in $SnO_2$ (*Phys. Rev. Lett.* 2002, ***88***, 095501).

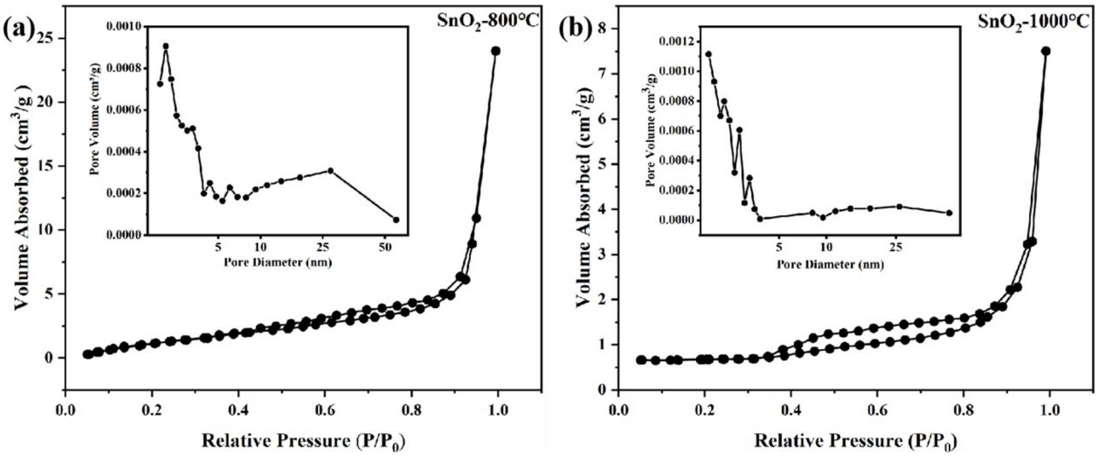


**Fig. S3** The $N_2$ sorption isotherms of pore $SnO_2$ (800 °C) and $SnO_2$ (1000 °C) measured at 77 K.

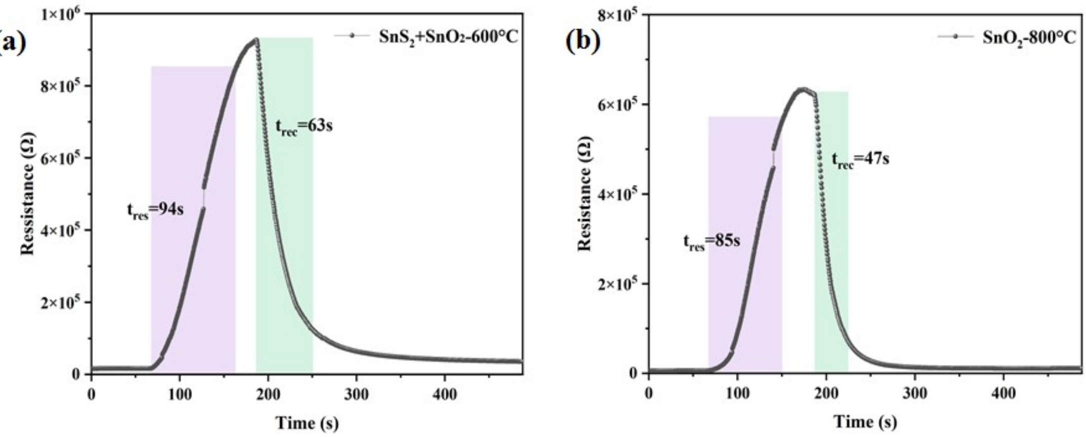


**Fig. S4** Respose/recovery times of $NO_2$ sensors made of (a) $SnS_2$-$SnO_2$ flakes (600 °C) and (b) $SnO_2$ flakes (800 °C).