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*Supplementary Materials*

# The Crucial Role of Support in the Pd/MO Catalyst for $SO_2$ Resistance during Toluene Combustion

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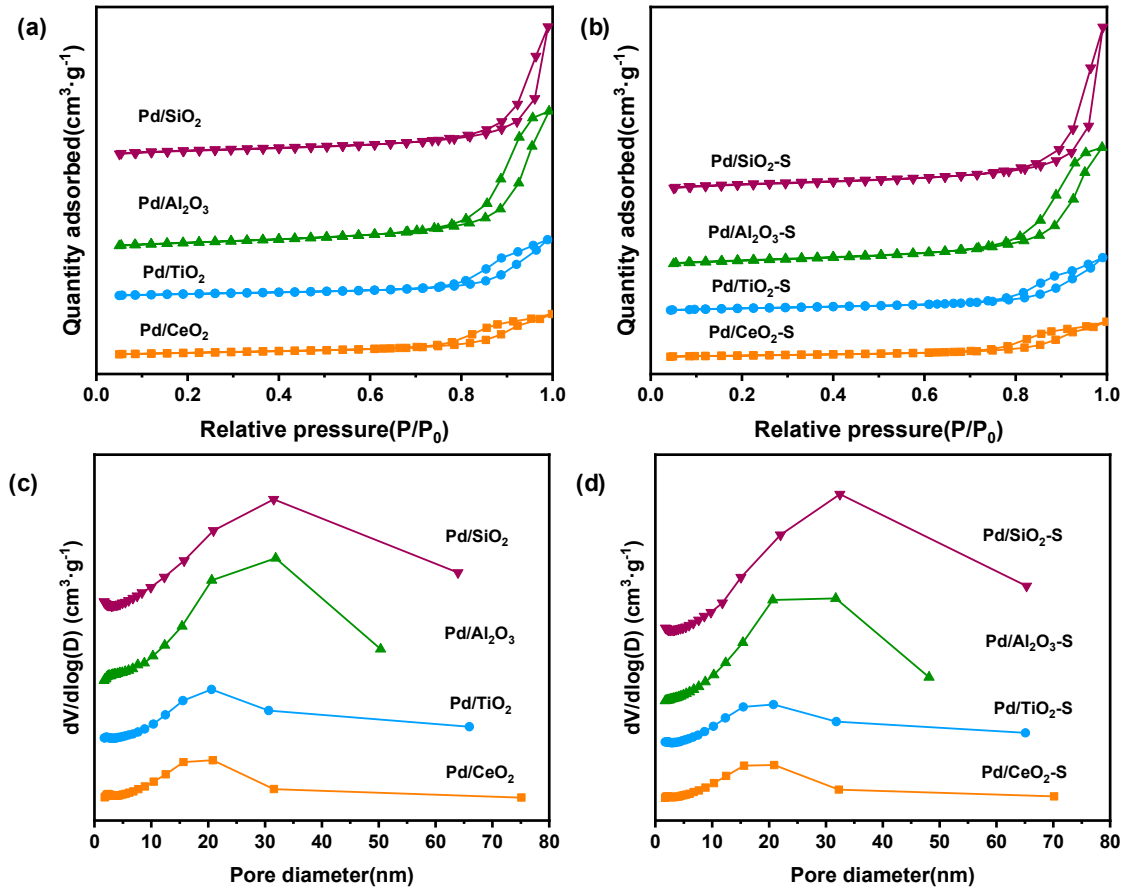


**Figure S1.** The $N_2$ adsorption-desorption isotherms and pore size distribution curves of samples: (**a**) and (**c**) fresh samples; (**b**) and (**d**) $SO_2$ pretreated samples.

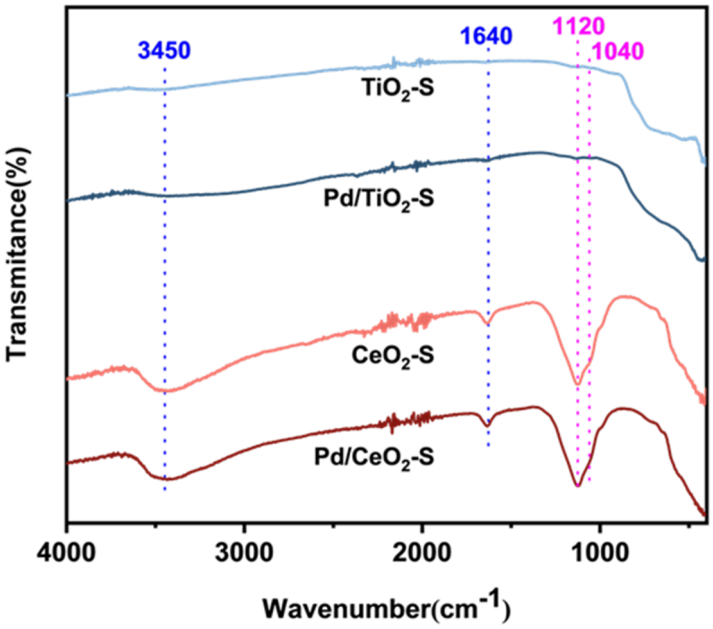


**Figure S2.** Comparison of the poisoning supports ($CeO_2$-S, $TiO_2$-S) and Pd-loaded samples (Pd/$CeO_2$-S, Pd/$TiO_2$-S).

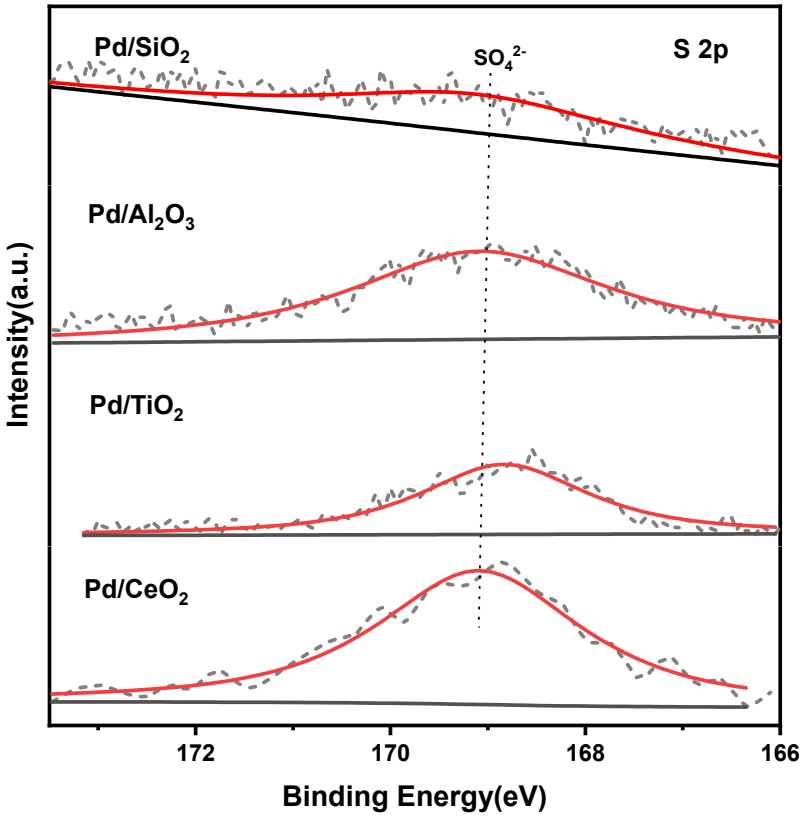


**Figure S3.** S 2p XPS spectra of the $SO_2$ pretreated samples.

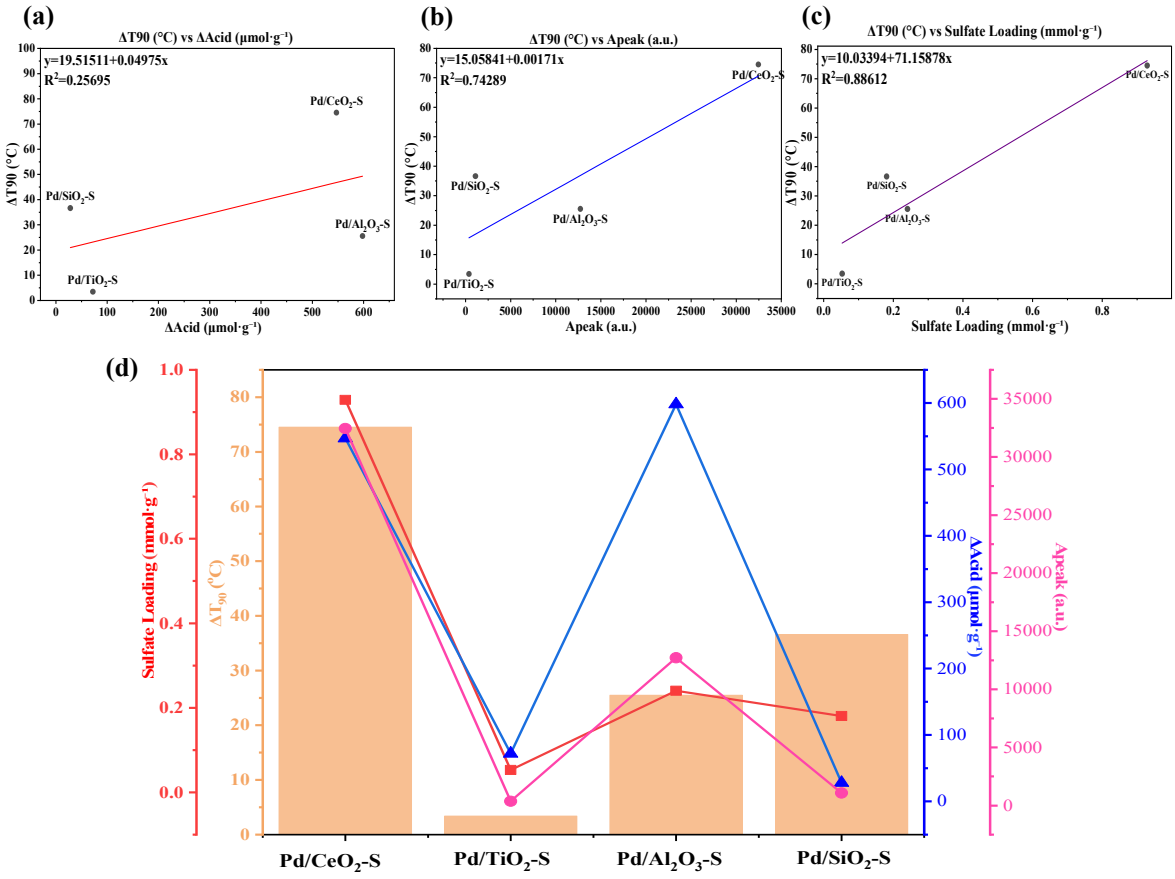


**Figure S4.** (**a**–**c**) Linear correlations between deactivation index $\Delta T_{90}$ and (**a**) total acid increment; (**b**) sulfate peak area; (**c**) sulfate loading for sulfated Pd-based catalysts; (**d**) Comparative performance of four catalysts, confirming sulfate accumulation as the primary deactivation driver.

**Table S1.** The actual Pd contents in fresh samples.

| Sample | Actual Pd Content(wt.%) |
|---|---|
| $Pd/CeO_2$ | 0.49 |
| $Pd/TiO_2$ | 0.46 |
| $Pd/Al_2O_3$ | 0.46 |
| $Pd/SiO_2$ | 0.45 |

**Table S2.** Sulfate loading and normalized activity loss of sulfur-poisoned Pd-based catalysts with different supports.

| Sample | Sulfate Loading (mmol·g$^{-1}$) | Sulfate Loading (wt %) | Normalized Activity Loss (%) |
|---|---|---|---|
| $Pd/CeO_2$-S | 0.0210 ± 0.0005 | 0.168 ± 0.004 | 33.96 |
| $Pd/TiO_2$-S | 0.0100 ± 0.0003 | 0.080 ± 0.002 | 1.34 |
| $Pd/Al_2O_3$-S | 0.0050 ± 0.0002 | 0.040 ± 0.002 | 10.97 |
| $Pd/SiO_2$-S | 0.0050 ± 0.0002 | 0.040 ± 0.002 | 15.31 |

Note: The normalized activity loss was used to evaluate the relative deactivation degree of catalysts after sulfur poisoning, and the sulfate loading on poisoned catalysts was quantified via thermogravimetric (TG) analysis. The calculation formulas are as follows:

1. $Sulfate\ Loading\ (mmol \cdot g^{-1}) = \frac{\Delta w \times 1000}{M_{SO_3}},\ Sulfate\ Loading\ (wt\%) = \Delta w \times 100\%$
2. $Normalized\ Activity\ Loss\ (\%) = \frac{\Delta T_{90}}{T_{90,fresh}} \times 100\%$

where $T_{90}$ is the temperature required for 90% toluene conversion of the catalyst; Δw is the mass loss rate of sulfate decomposition measured by TG test (g·g$^{-1}$); M_SO₃ is the molar mass of sulfur trioxide (fixed at 80.06 g·mol$^{-1}$). Positive values of $\Delta T_{90}$ indicate increased $T_{90}$ (catalyst deactivation), with higher values representing more severe deactivation.

**Table S3.** The XPS data of all as-prepared samples.

| Sample | $Pd^0/Pd_{total}$ (%) | $\Delta Pd^0$ (%) | $O_{ads}/O_{total}$ (%) | $\Delta O_{ads}$ (%) |
|---|---|---|---|---|
| $Pd/CeO_2$ | 28.2 | 8.4 | 37.7 | 11.5 |
| $Pd/CeO_2$-S | 19.8 | | 49.2 | |
| $Pd/TiO_2$ | / | / | 17.8 | 4.1 |
| $Pd/TiO_2$-S | / | | 21.9 | |
| $Pd/Al_2O_3$ | 12.9 | 3 | 30.4 | 9.8 |
| $Pd/Al_2O_3$-S | 9.9 | | 40.2 | |
| $Pd/SiO_2$ | 11.8 | 3.7 | / | / |
| $Pd/SiO_2$-S | 8.1 | | / | |

**Table S4.** The quantitative analysis results of $NH_3$-TPD of fresh and $SO_2$ pretreated samples.

| Sample | Weak Acidity | | Moderate Acidity | | Strong Acidity | | Total Amount ($\mu mol \cdot g^{-1}$) |
|---|---|---|---|---|---|---|---|
| | Amount ($\mu mol \cdot g^{-1}$) | Temp. (°C) | Amount ($\mu mol \cdot g^{-1}$) | Temp. (°C) | Amount ($\mu mol \cdot g^{-1}$) | Temp. (°C) | |
| $Pd/CeO_2$ | 47 | 191 | 142 | 246 | / | / | 189 |
| $Pd/CeO_2$-S | 301 | 190 | 354 | 305 | 81 | 371 | 736 |
| $Pd/TiO_2$ | 17 | 127 | 44 | 217 | 11 | 336 | 72 |
| $Pd/TiO_2$-S | 18 | 108 | 108 | 210 | 18 | 471 | 144 |
| $Pd/Al_2O_3$ | 307 | 107, 180 | 94 | 320 | / | / | 401 |
| $Pd/Al_2O_3$-S | 158 | 121 | 598 | 210 | 243 | 380 | 999 |
| $Pd/SiO_2$ | 278 | 103, 164 | / | / | / | / | 278 |
| $Pd/SiO_2$-S | 121 | 120 | 154 | 205 | 31 | 360 | 306 |