

Supporting information

## **Synergetic effect metal-support for enhanced performance of Cu-ZnO-ZrO<sub>2</sub>/UGSO catalyst for CO<sub>2</sub> hydrogenation to methanol**

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**Table S1.** Reducibility of CZxZr/UGSO catalysts.

**Table S2.** Comparison of catalytic performance of our developed catalysts and some other catalysts in CO<sub>2</sub> hydrogenation into methanol.

**Figure S1.** N<sub>2</sub> adsorption-desorption isotherms (A) and pore size distributions (B) of UGSO and CZxZr/UGSO samples.

**Figure S2.** H<sub>2</sub>-TPR profiles of UGSO and CZxZr/UGSO from 50 to 900 °C.

**Figure S3.** CO<sub>2</sub>-TPD profiles of (A) CZ3Zr/UGSO, (B) CZ6Zr/UGSO, (C) CZ9Zr/UGSO, and (D) CZ12Zr/UGSO.

**Figure S4.** XRD patterns of (A) calcined UGSO, UGSO-H, CZ9Zr/UGSO and CZ9Zr/UGSO-H; (B) reduced CZ9Zr/UGSO and CZ9Zr/UGSO-H.

**Figure S5.** XPS spectra of surface elements in calcined samples (A) Mg 2p, (b) Fe 2p, (C) Cu 2p.

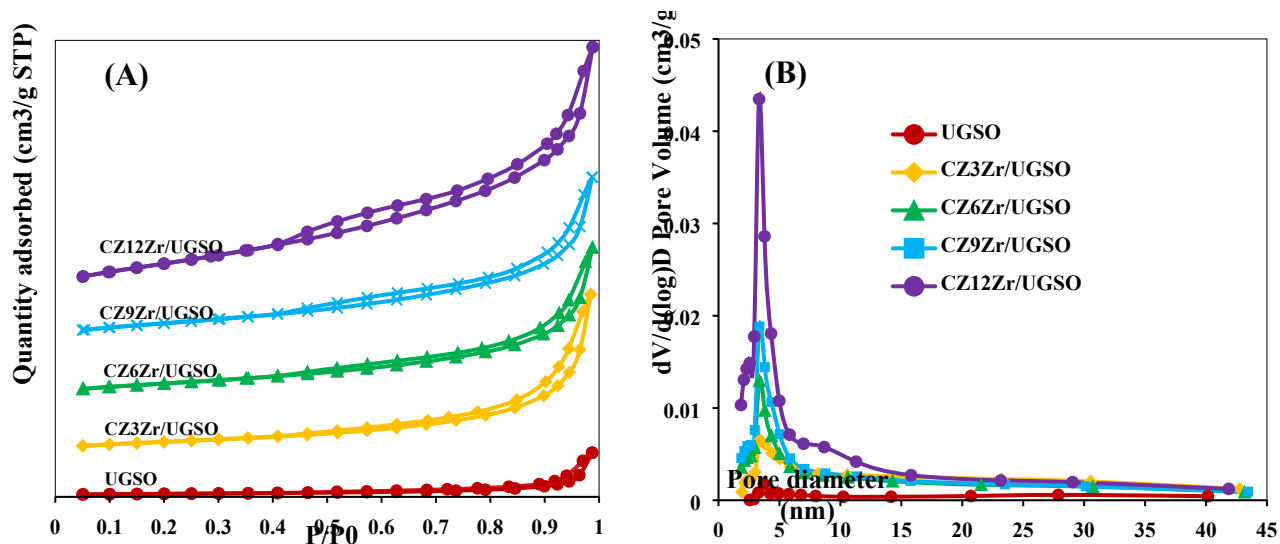
**Table S1.** Reducibility of CZ<sub>x</sub>Zr/UGSO catalysts.

Sample	Peak $\alpha$		Peak $\beta$		Peak $\gamma$	
	T (°C)	% Area	T (°C)	% Area	T (°C)	% Area
CZ3Zr/UGSO	191	15.8	210	34.4	236	49.8 <sup>1</sup>
CZ6Zr/UGSO	186	22.8	204	63.0	222	14.1
CZ9Zr/UGSO	178	6.3	202	74.9	206	18.7
CZ12Zr/UGSO	187	22.0	200	64.2	205	13.8

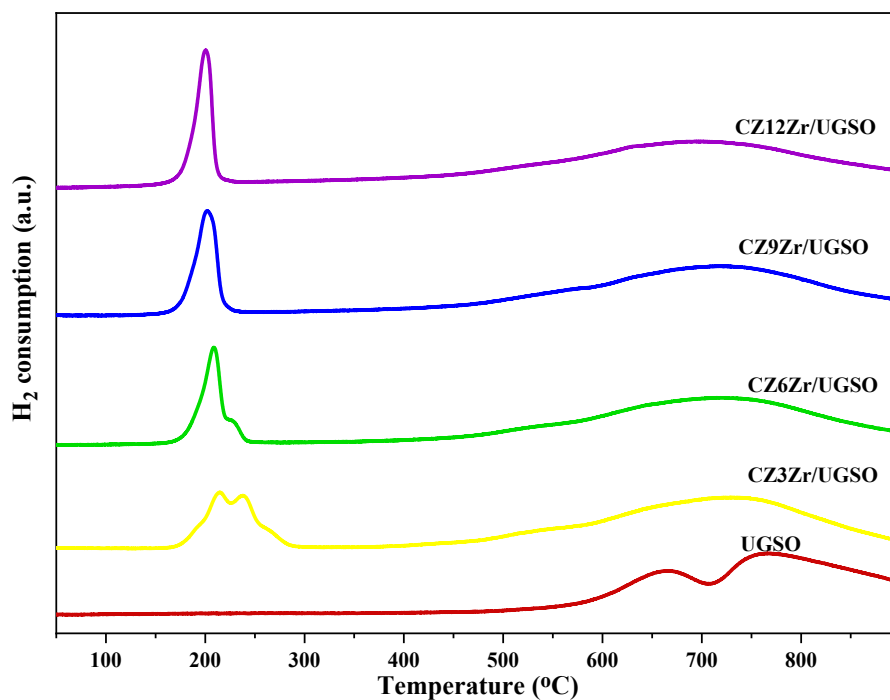
<sup>1</sup>calculated based on the total area of  $\gamma$  and  $\lambda$  peaks.

**Table S2.** Comparison of catalytic performance of our developed catalysts and some other catalysts in CO<sub>2</sub> hydrogenation into methanol.

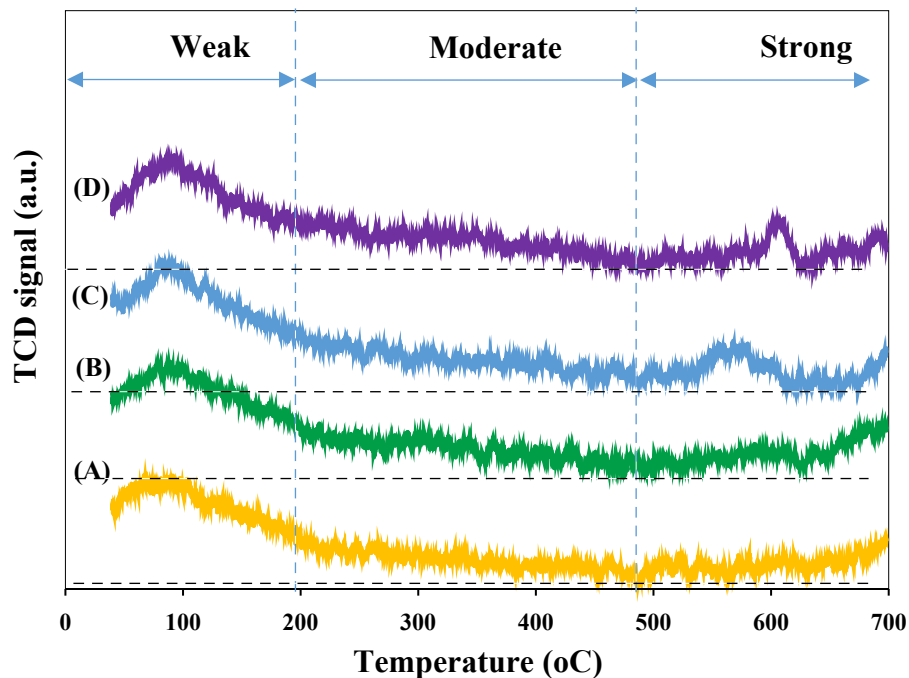
Catalyst	T (°C)	P (bar)	Conv. (%)	Sel. <sub>MeOH</sub> (%)	Yield <sub>MeOH</sub> (%)	Ref & Year
CZ9Zr/UGSO	240	20	4.8	31.5	<b>1.51</b>	This work
CZ9Zr/UGSO-H	240	20	7.0	26.1	<b>1.82</b>	This work
Cu-ZnO-ZrO <sub>2</sub> @Al-TUD-1	240	20	2.5	39.3	0.98	<sup>77</sup>
Cu-ZnO-ZrO <sub>2</sub> @Al-TUD-1	260	20	5.9	27.5	1.62	<sup>77</sup>
YBa <sub>2</sub> Cu <sub>3</sub> O <sub>7</sub>	240	30	3.0	38.4	1.2	<sup>78</sup>
Cu/ZnAl <sub>2</sub> O <sub>4</sub>	250	20	4.0	21.0	0.80	<sup>79</sup>
Cu-In-Zr-O	250	25	1.5	80.0	1.20	<sup>80</sup>
Cu-ZrO <sub>2</sub>	270	20	2.7	41.0	1.10	<sup>81</sup>
Pd-Ga <sub>2</sub> O <sub>3</sub> /SiO <sub>2</sub>	250	30	1.3	58.9	0.79	<sup>82</sup>
Pd-Ca/MCM41	250	41	5.0	28.0	1.40	<sup>83</sup>
Pd-K/SBA-15	250	41	14.0	11.0	1.54	<sup>83</sup>



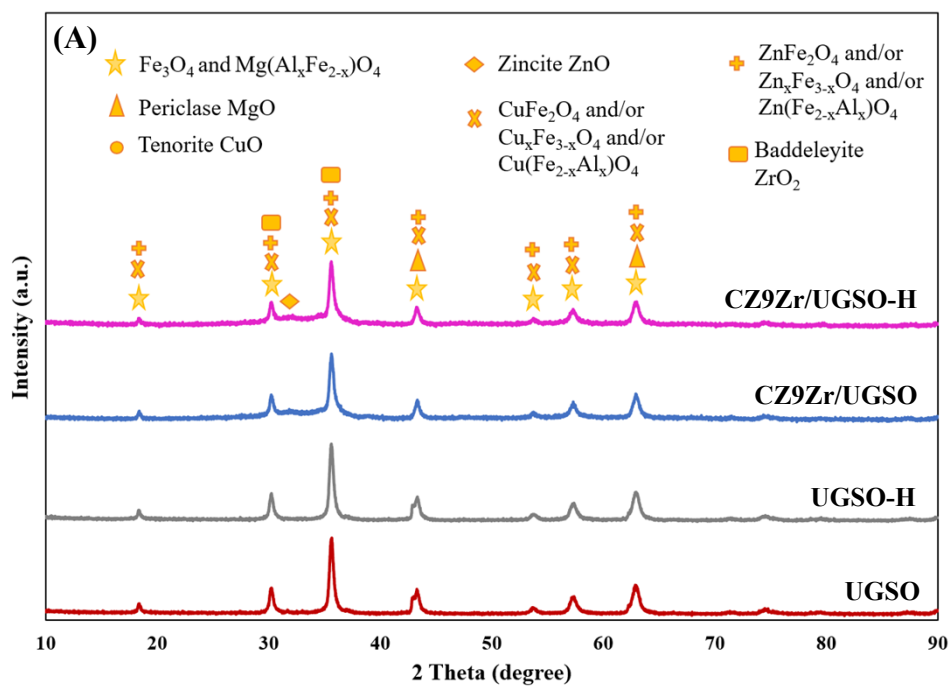
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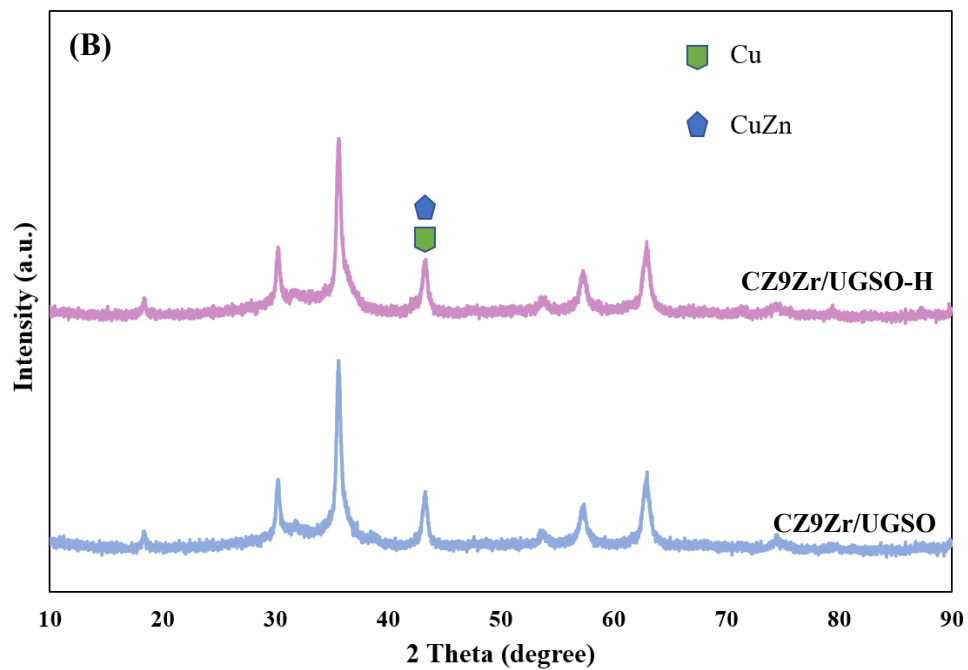


**Figure S2.** H<sub>2</sub>-TPR profiles of UGSO and CZ<sub>x</sub>Zr/UGSO from 50 to 900 °C.

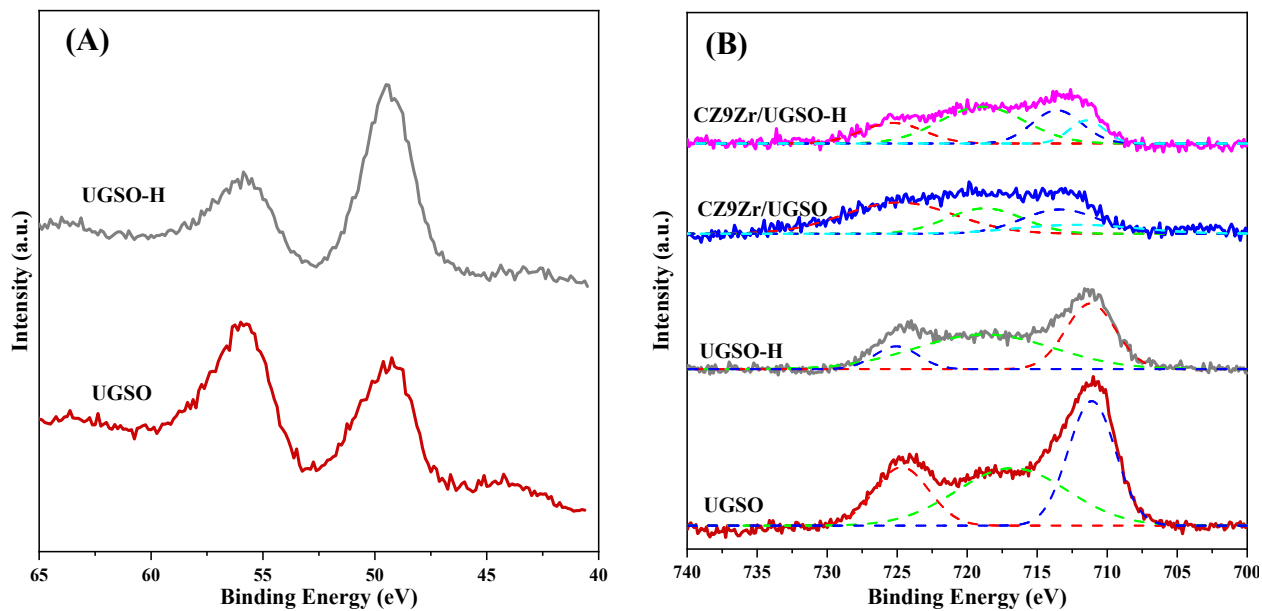


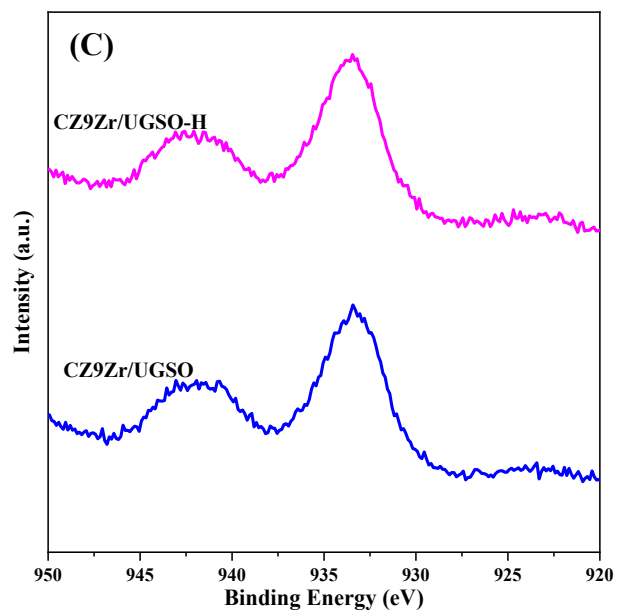
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**Figure S5.** XPS spectra of surface elements in calcined samples (A) Mg 2p, (b) Fe 2p, (C) Cu 2p.