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Electronic Supplementary Information

Metal-Support Interaction Induced ZnO Overlayer in Cu@ZnO/Al_2O_3 Catalysts toward Low-Temperature Water Gas Shift Reaction

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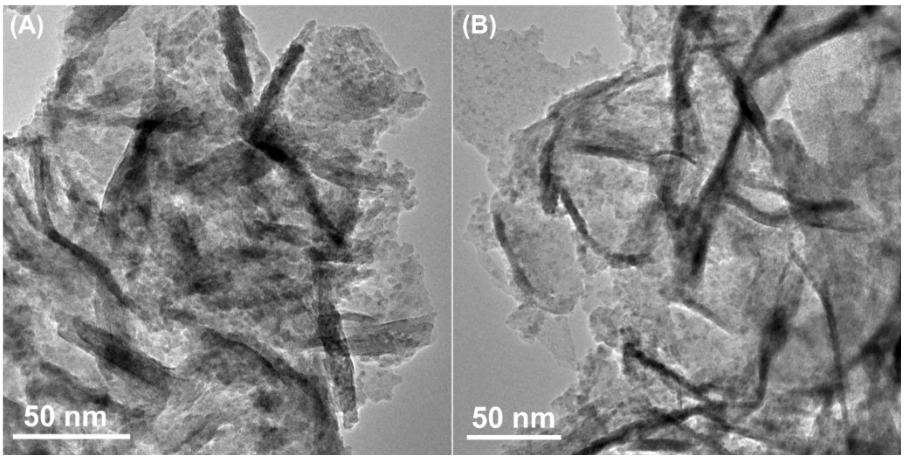

Figure S1. (A–B) TEM images of Cu_2Zn_1Al-LDHs.

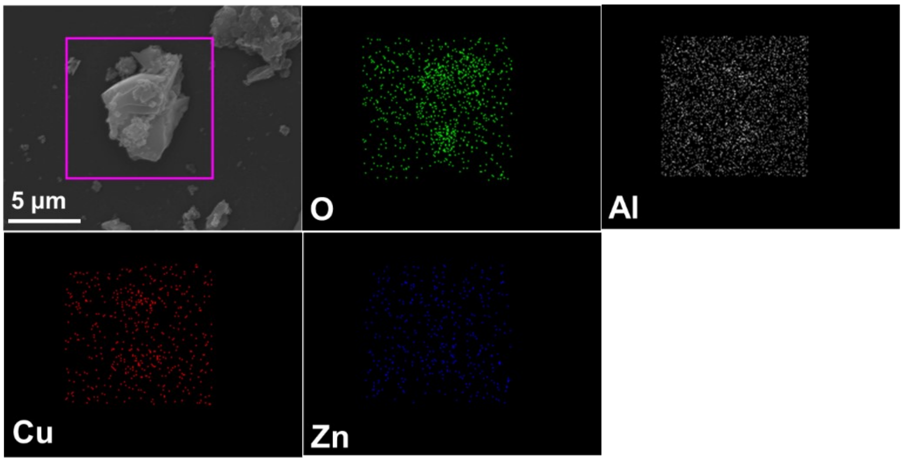

Figure S2. SEM image of Cu_2Zn_1Al-LDHs and the corresponding element EDS mapping of Cu, Zn, Al, and O.

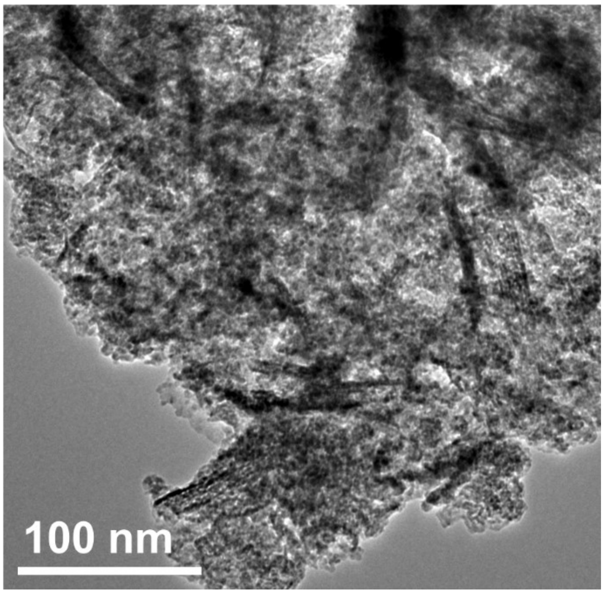

Figure S3. TEM images of Cu@ZnO/Al_2O_3-300R.

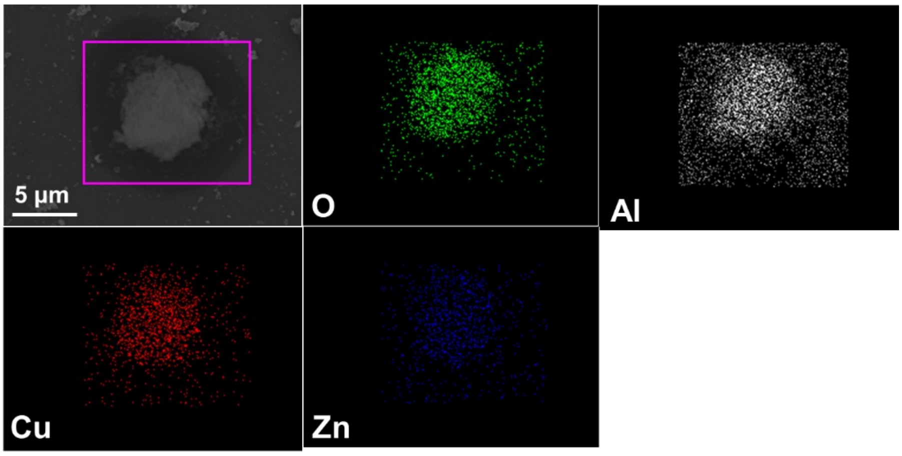

Figure S4. SEM image of Cu@ZnO/Al_2O_3-300R and the corresponding element EDS mapping of Cu, Zn, Al, and O.

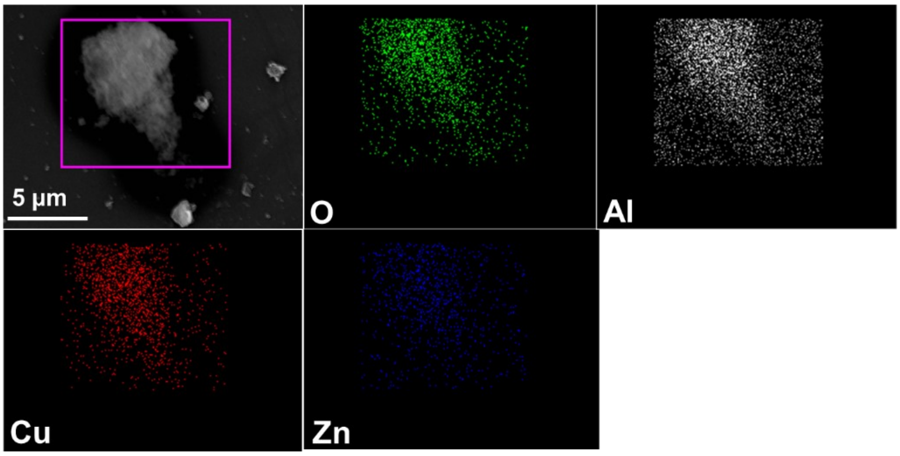

Figure S5. SEM image of Cu@ZnO/Al_2O_3-350R and the corresponding element EDS mapping of Cu, Zn, Al, and O.

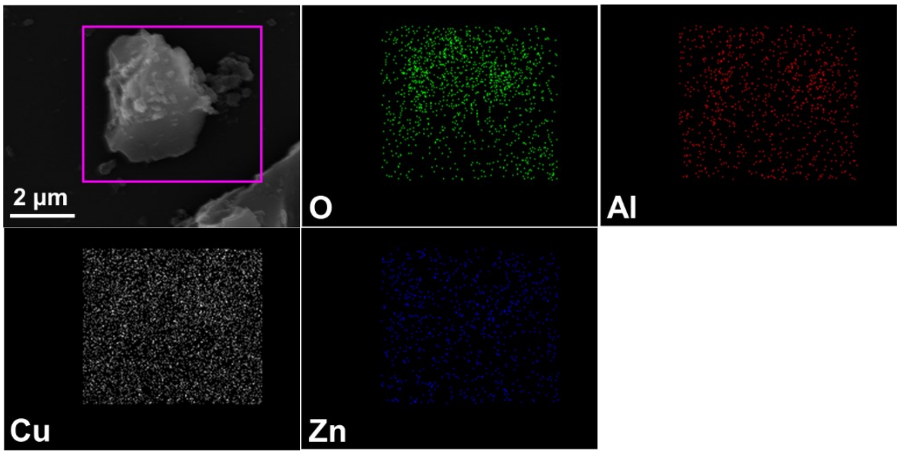

Figure S6. SEM image of Cu@ZnO/Al_2O_3-400R and the corresponding element EDS mapping of Cu, Zn, Al, and O.

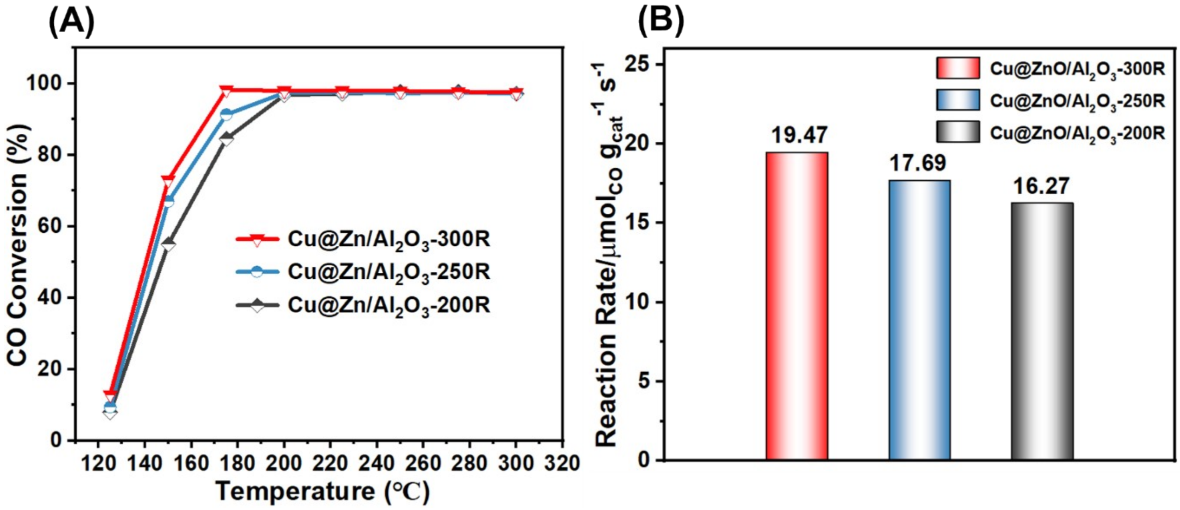

Figure S7. (A) CO conversion as a function of reaction temperature over the Cu@ZnO/Al_2O_3 catalysts (WGS reaction conditions: 6% CO, 25% H_2O, 69% Ar; WHSV: 15700 mL g_{cat}^{-1} h^{-1}). (B) Reaction rates of Cu@ZnO/Al_2O_3-300R, Cu@ZnO/Al_2O_3-250R and Cu@ZnO/Al_2O_3-200R catalysts at 175 °C.

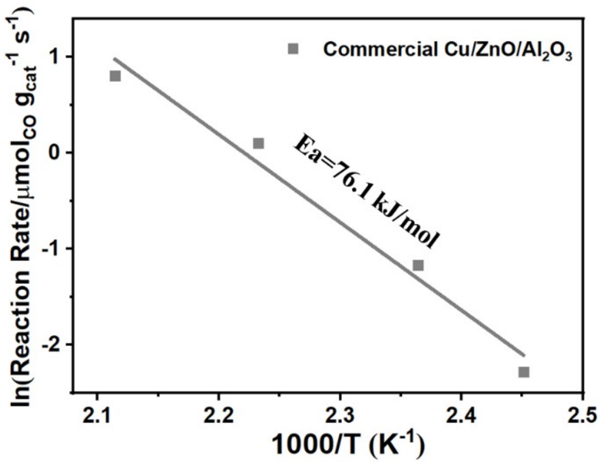

Figure S8. Arrhenius plots of WGS reaction over the commercial Cu/ZnO/Al_2O_3 catalyst. (WGS reaction conditions: 6% CO, 25% H_2O, 69% Ar)

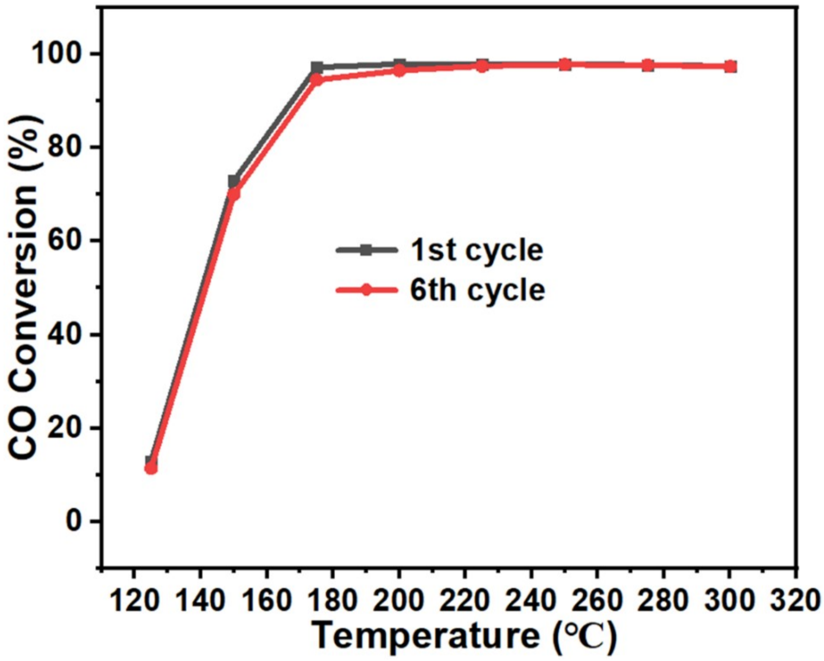

Figure S9. CO conversion as a function of reaction temperature over the Cu@ZnO/Al_2O_3-300R catalyst (WGS reaction conditions: 6% CO, 25% H_2O, 69% Ar; WHSV: 15700 mL g_{cat}^{-1} h^{-1}).

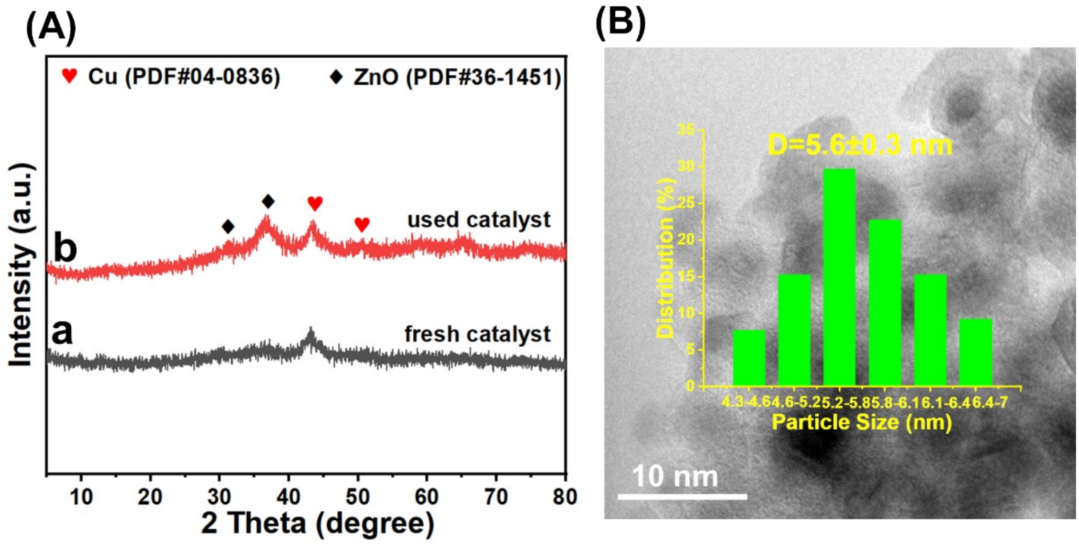

Figure S10. (A) XRD patterns of the Cu@ZnO/Al_2O_3-300R catalyst: (a) the fresh catalyst (b) the used catalyst after five cycles test. (B) TEM images of the used Cu@ZnO/Al_2O_3-300R catalyst after five cycles test.

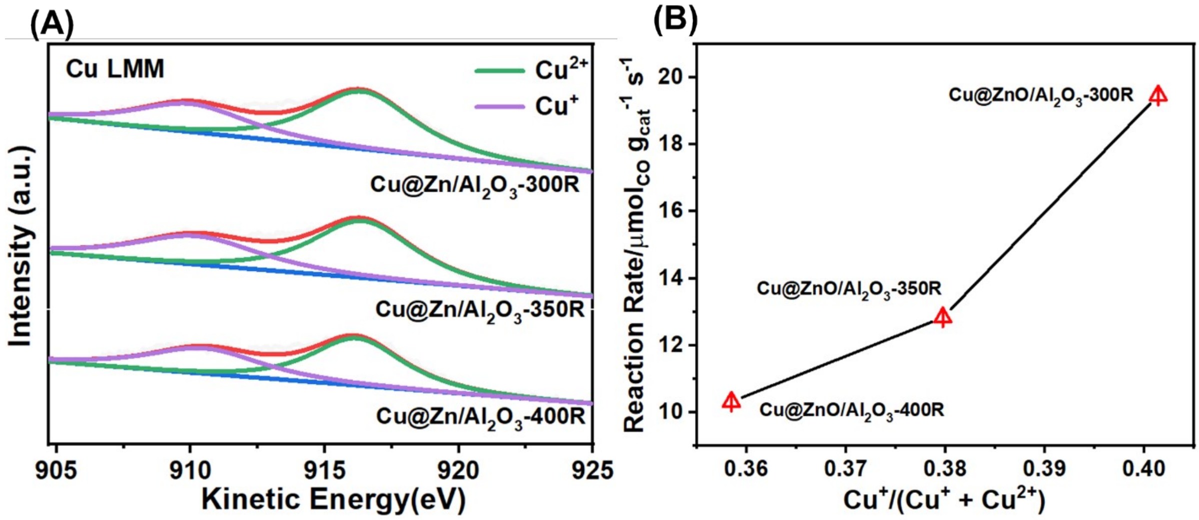

Figure S11. (A) XAES spectra of Cu LMM for Cu@ZnO/Al_2O_3-300R, Cu@ZnO/Al_2O_3-350R, and Cu@ZnO/Al_2O_3-400R. (B) Reaction rate as a function of surface Cu^+ concentration.

Table S1. Physicochemical properties of Cu@ZnO/Al_2O_3-300R catalyst before and after five cycles test

catalysts	Cu species content[a] (wt %)	Zn species content[a] (wt %)	Al species content[a] (wt %)	Cu crystallite size[b] (nm)	mean Cu particle size[c] (nm)
Cu@ZnO/Al_2O_3-300R (fresh)	27.5	13.9	47.1	7.6	5.4
Cu@ZnO/Al_2O_3-300R (used)	27.1	13.6	47.0	7.9	5.6

[a] Element content was determined by inductively coupled plasma–atomic emission spectroscopy (ICP–AES). [b] Crystallite size of Cu was determined by XRD with the Scherrer equation. [c] Mean particle size of Cu was determined by TEM.

Table S2. Physicochemical properties of Cu@ZnO/Al_2O_3-300R catalyst before and after stability test

catalysts	Cu species content[a] (wt %)	Zn species content[a] (wt %)	Al species content[a] (wt %)	Cu crystallite size[b] (nm)	mean Cu particle size[c] (nm)
Cu@ZnO/Al_2O_3-300R (fresh)	27.5	13.9	47.1	7.6	5.4
Cu@ZnO/Al_2O_3-300R (used)	27.7	14.3	47.4	8.0	5.8

[a] Element content was determined by inductively coupled plasma–atomic emission spectroscopy (ICP–AES). [b] Crystallite size of Cu was determined by XRD with the Scherrer equation. [c] Mean particle size of Cu was determined by TEM.

Table S3. Comparison of catalytic performances for WGSR over various catalysts

Catalyst	Reaction Temperature (°C)	Reaction Condition	Reaction Rate ($\mu mol_{CO}\ g_{cat}^{-1}s^{-1}$)	Ref.
Cu@ZnO/Al_2O_3-300R	175	6%CO-25%H_2O-Ar	19.47	This work
Cu@ZnO/Al_2O_3-350R	175	6%CO-25%H_2O-Ar	12.83	This work
Cu@ZnO/Al_2O_3-400R	175	6%CO-25%H_2O-Ar	10.31	This work
Cu/ZnO/Al_2O_3	175	6%CO-25%H_2O-Ar	3.58	This work
$Cu_{8.9}/CeO_2$	300	10% CO, 20% H_2O, balance He	16.7	*Catal. Today* **2008**, *137*, 29
Cu/CeO_2	200	1.0 vol.% CO, 3.0 vol.% H_2O/He	4.0	*Nat. Catal.* **2019**, *2*, 334
ZnO/c-Cu	225	5% CO, 10% H_2O, balance Ar	1.2	*Nat. Commun.* **2017**, *8*, 488
Cu/ZnO/La	230	7% CO, 8.5% CO_2, 23% H_2O, 37.5% H_2 and 25% N_2	11.7	*J. Catal.* **2010**, *273*, 73
$Ce_{0.75}Cu_{0.1}Ni_{0.15}O_{2-\delta}$	240	1.3% CO, 35% H_2O	2.2	*Appl. Catal. B: Environ.* **2012**, *123*, 367
$Cu_4Ni_{16}/CeLaO_x$	275	10% CO, 20% H_2O, balance He	15.6	*Appl. Catal., A* **2010**, *387*, 87
Au@TiO_{2-x}/ZnO(H300)	250	6%CO-25%H_2O-Ar	15.2	*ACS Catal.* **2019**, **9**, 2707
Au/CeO_2	150	2%CO-10%H_2O-He	2.38	*Angew. Chem. Int. Ed.* **2008**, *47,* 2884
Au/CeFeAl	180	4.5%CO-30%H_2O-N_2	1.98	*J. Catal.* **2014**, *314,* 1