Electronic Supplementary Information (ESI)

Ruthenium supported on zirconia-carbon nanocomposites derived by UiO-66 for efficient photothermal catalytic CO_2 reduction

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Supplementary Materials Include:

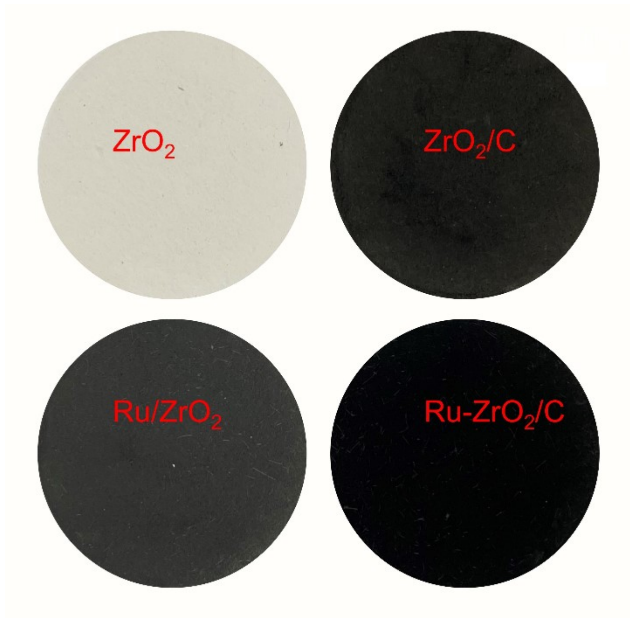

Fig. S1 the images of ZrO_2, ZrO_2/C, Ru/ZrO_2, and $Ru\text{-}ZrO_2/C$.

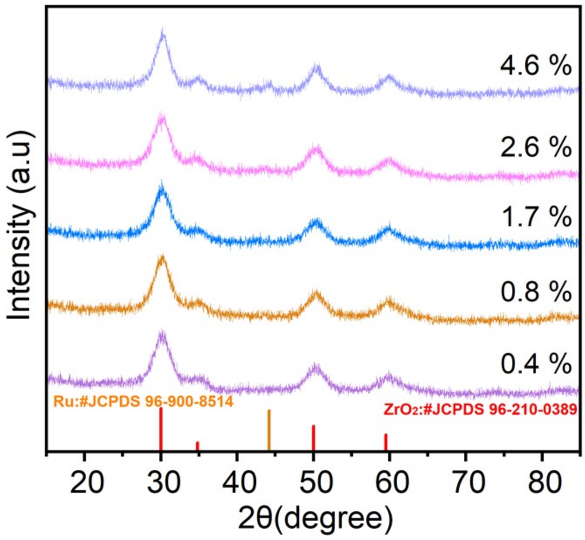

Fig. S2 XRD patterns of xRu-ZrO_2/C with different Ru loading amounts, ZrO_2 represents JCPDS PDF # 96-210-038, and Ru represents JCPDS PDF # 96-900-8514.

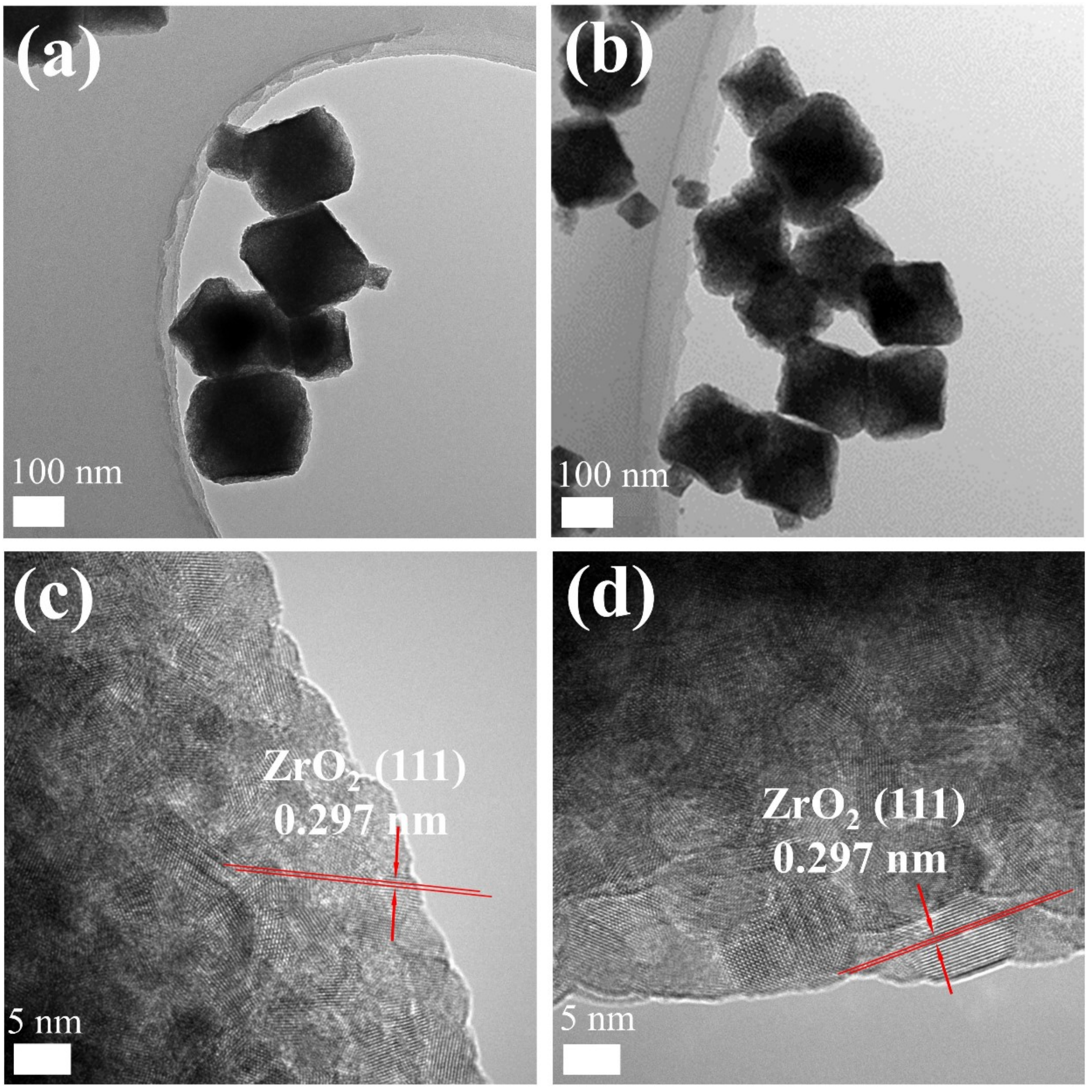

Fig. S3 SEM and HRTEM images. (a–b) TEM images of ZrO_2/C and ZrO_2; (c–d) HRTEM images of ZrO_2/C and ZrO_2, respectively.

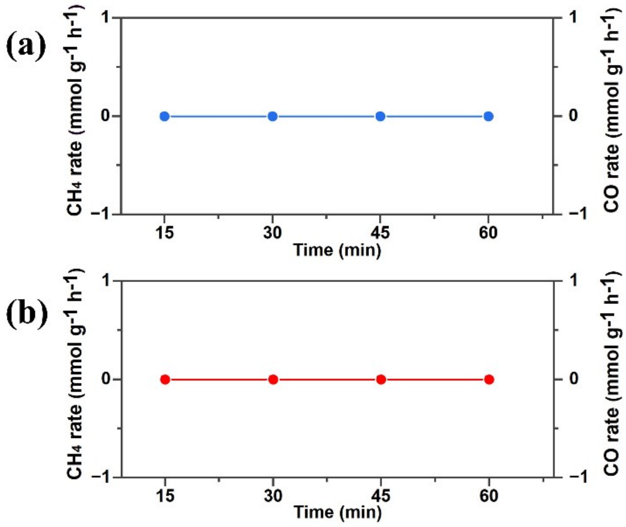

Fig. S4 (a) Production rate of ZrO_2/C with a continuous flow of 10 vol.% CO_2, 40 vol.% H_2, and 50 vol.% He (25 mL/min); (b) Production rate of Ru-ZrO_2/C with a continuous flow of 5% vol.% H_2 and 95% vol.% Ar (25 mL/min). Reaction condition: the samples were irradiated under full-spectrum irradiation with light intensities (2614 mW cm^{-2}).

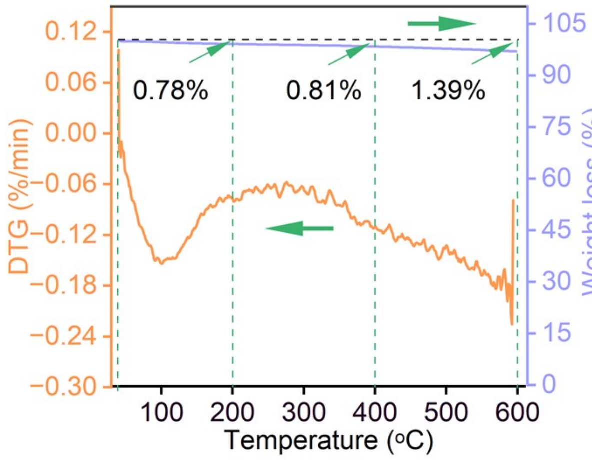

Fig. S5 Thermogravimetry analysis and derivative thermogravimetry (TGA-DTG) curve of Ru-ZrO_2/C

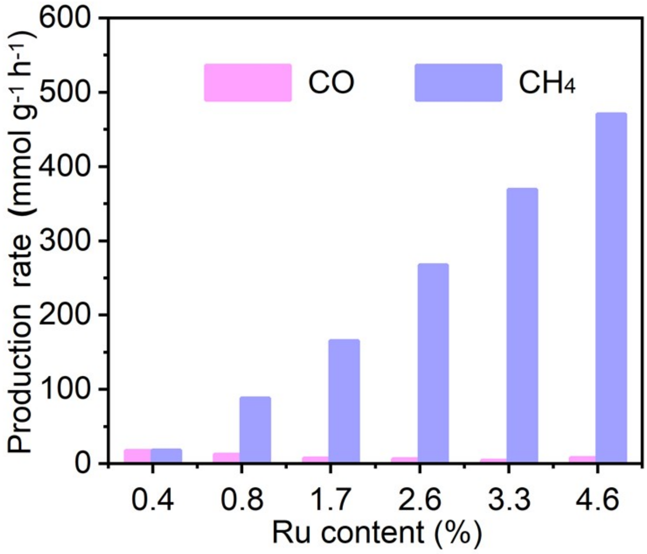

Fig. S6 The production rate in the initial second hours of Ru-ZrO_2/C with different Ru loading amounts at the light intensity of 2614 mW cm^{-2}.

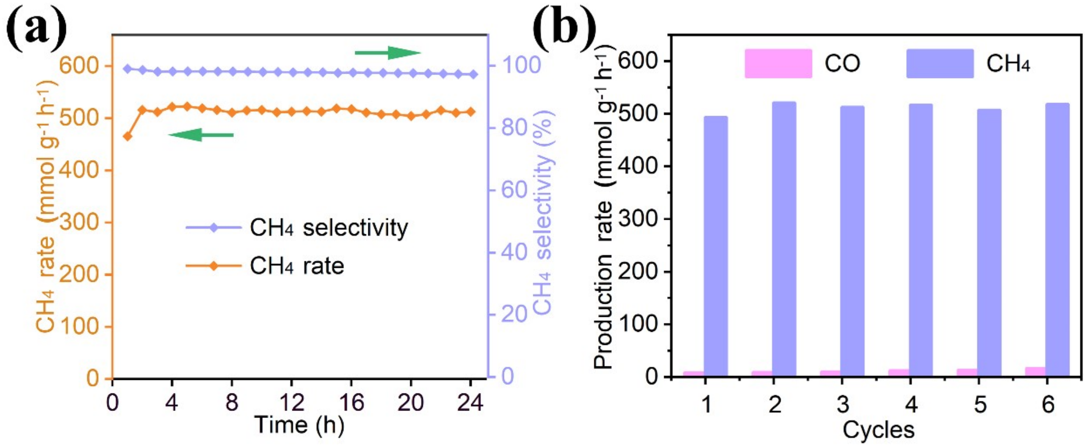

Fig. S7 (a) Continuous stability test of photothermal CO_2 reduction over Ru-ZrO_2/C under the light intensity of 2858 mW cm^{-2} for 24 h. (b) The catalytic durability for CO_2 reduction over Ru-ZrO_2/C under the light intensity of 2858 mW cm^{-2}, lasting within at least 24 h (each cycle for 4 h, 6 cycles)

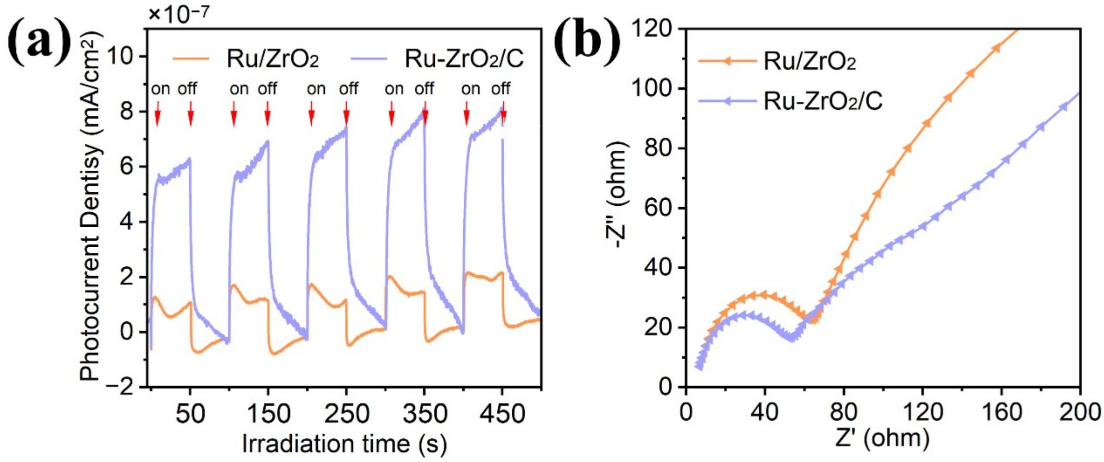

Fig. S8 (a) photocurrent test of Ru/ZrO_2 and $Ru\text{-}ZrO_2/C$; (b) EIS Nyquist plots under irradiation of Ru/ZrO_2 and $Ru\text{-}ZrO_2/C$

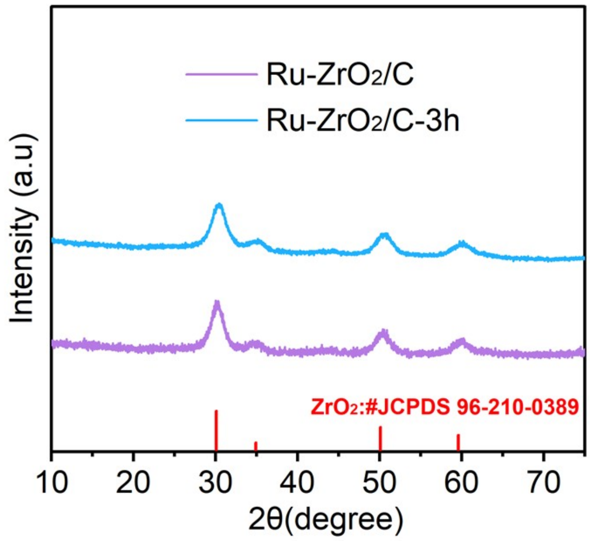

Fig. S9 XRD patterns of Ru-ZrO_2/C and Ru-ZrO_2/C-3h, ZrO_2 represents JCPDS PDF # 96-210-038.

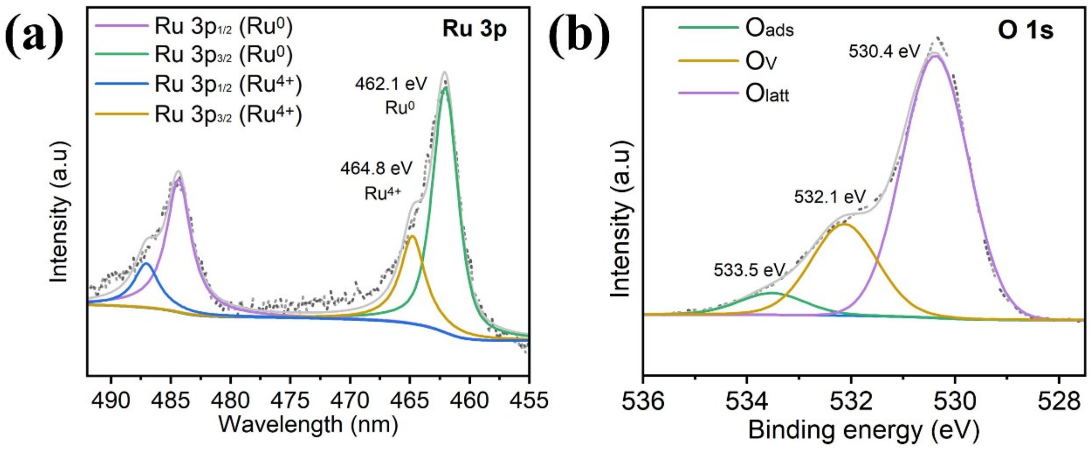

Fig. S10 Ru 3p and O 1s of the Ru-ZrO_2/C-3h, respectively.

Table S1 Catalytic activity for CH_4 production via photo-thermal route in the reported literature

Catalysts	**Surface temperature (°C)**	**CH_4 production (mmol $g_{cat}^{-1}h^{-1}$)**	**Literature**
Ru-ZrO_2/C	370	504.1	This work
Ru/CeO_2	365	16.8	Ref.[1]
Ru/MnO-$MgCO_3$	400	50.7	Ref.[2]
Ru@$Ni_2V_2O_7$	350	114.9	Ref.[3]
Ru@FL-LDH	350	277.0	Ref.[4]
Ru/pBN-1.76%F	400	115.7	Ref.[5]
3Ru/CeO_2	350	227.7	Ref.[6]
5%Ru/Al_2O_3	400	271.0	Ref.[7]
5%Ru/CeO_2	400	147.0	Ref.[7]
12Co/MnO	420	121.4	Ref.[8]
Ru/Al_2O_3-B	350	34.3	Ref.[9]
Ni@CeO_2	420	257.4	Ref.[10]

Table S2 Vibrational wavenumbers were measured in this work and collected from the literature.

Position (cm^{-1})	corresponding	Literature
1230	HCOO*	Ref.[11]
1513,1547,1581	b-CO_3^{2-}	Ref.[12]
1641	CH_3O^-	Ref.[13, 14]
1900-2100	CO	Ref.[15, 16]
1305,3016	CH_4	Ref.[17, 11]

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