

Electronic supplementary information

**Low temperature benzene oxidation over copper-silver catalyst: roles of
copper oxide and silver on cerium-zirconium mixed oxide†**

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Table S1 Elemental composition of CZCuAg (CZ:Cu:Ag = 1:0.5:0.5) measured by ICP-AES

Element	Cu	Ag	Si	Na
Content (wt.%)	13.6	19.3	0.0062	n.d. ^a

^a Detection limit of Na < 0.00030 wt.% (3.0 ppm)

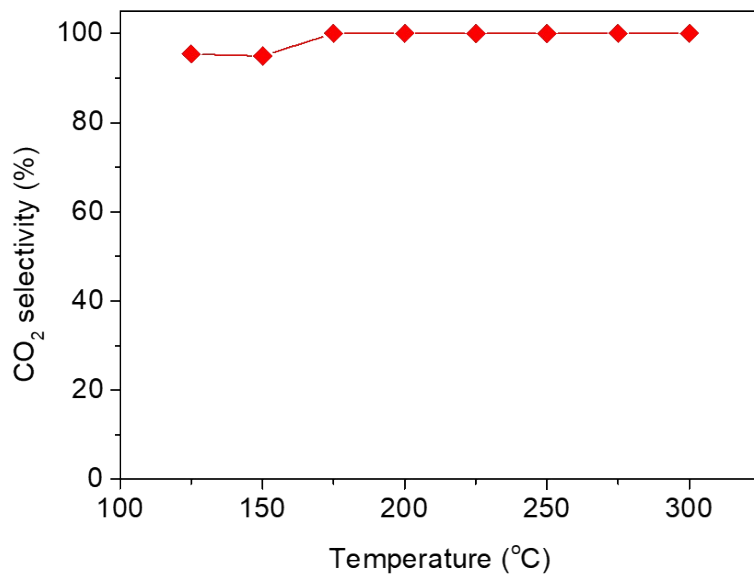


Fig. S1 CO₂ selectivity as a function of temperature over the CZCuAg (CZ:Cu:Ag = 1:0.5:0.5) catalyst. Feed gas composition: 150 ppm C₆H₆, 2.5 vol.% H₂O, air balance. GHSV = 100,000 h⁻¹.

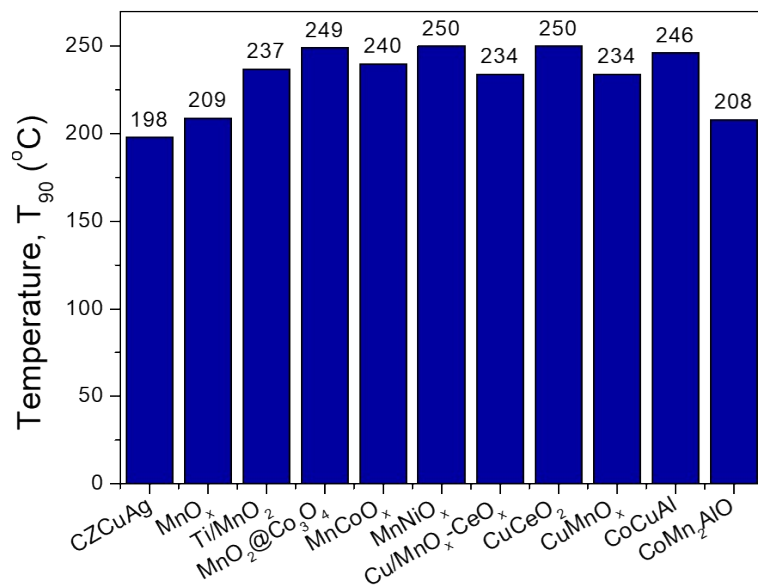


Fig. S2 Comparison of the catalytic activities of CZCuAg and some reported catalysts for benzene oxidation.¹

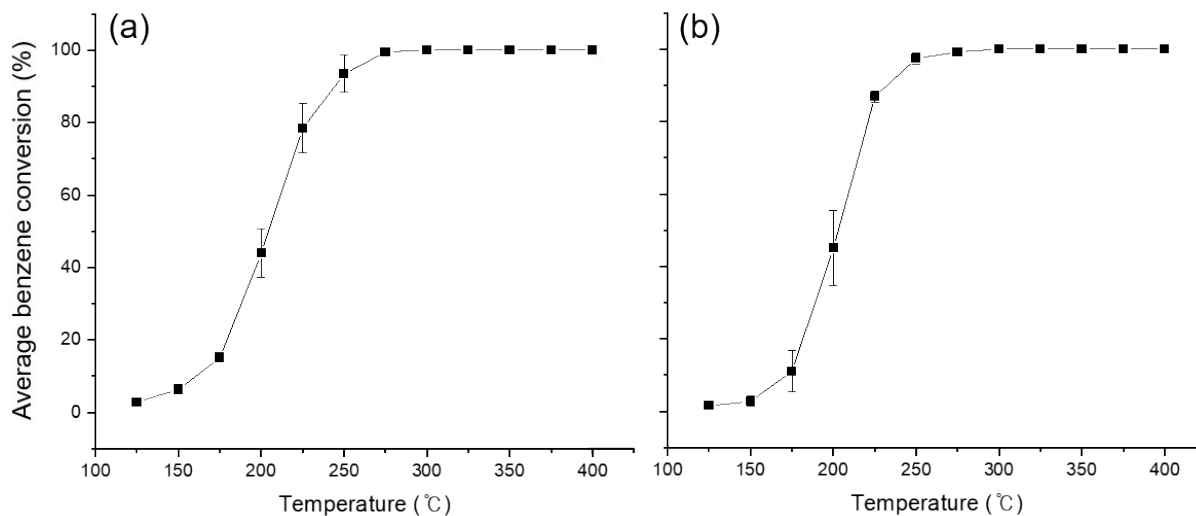


Fig. S3 Average benzene conversion as a function of reaction temperature obtained from three repeated reproducibility tests for benzene oxidation over (a) CZCuAg (CZ:Cu:Ag = 1:0.5:0.5) and (b) PtPd/γ-Al₂O₃ catalysts. Feed gas composition: 150 ppm C₆H₆, 2.5 vol.% H₂O, air balance. GHSV = 100,000 h⁻¹.

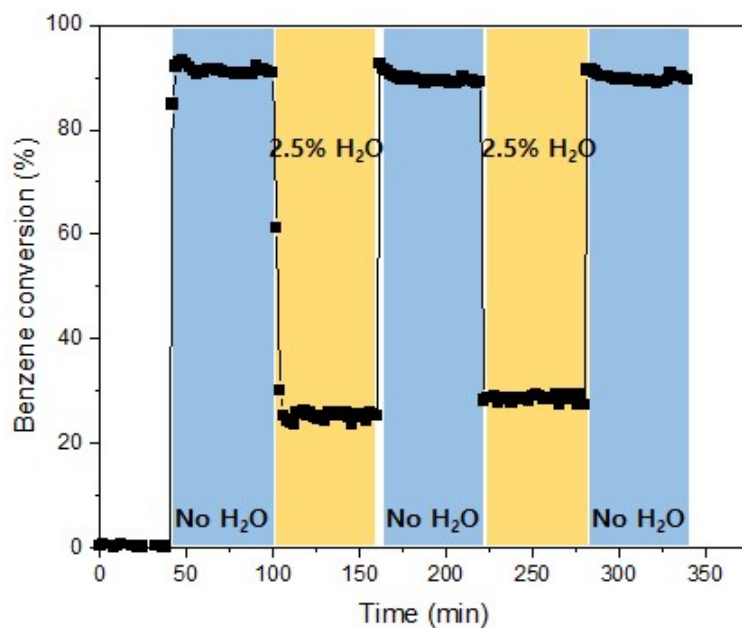


Fig. S4 Benzene oxidation catalyzed by CZCuAg (CZ:Cu:Ag = 1:0.5:0.5) under water on/off cycle. 150 ppm/air balance C₆H₆ was fed into the catalyst bed at 250 °C with GHSV = 100,000 h⁻¹ under 2.5 vol.% H₂O on/off cycle.

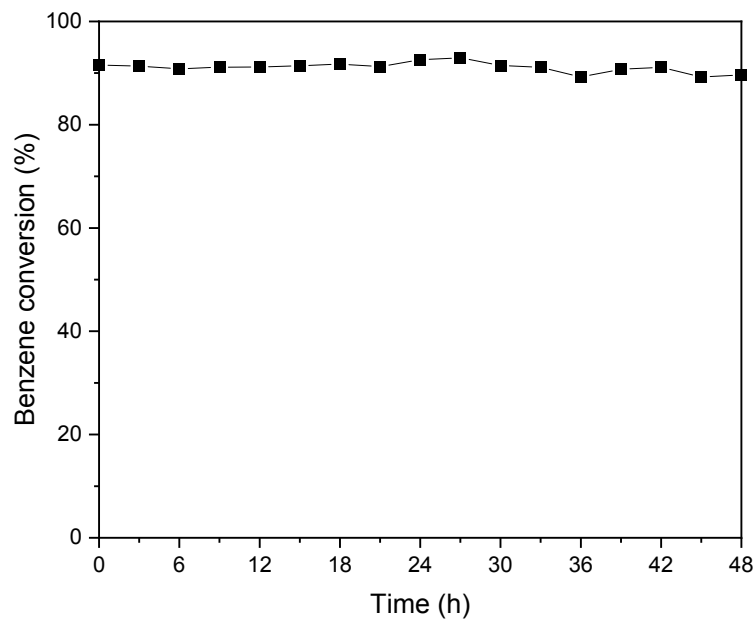


Fig. S5 Benzene oxidation catalyzed by CZCuAg (CZ:Cu:Ag = 1:0.5:0.5) at 250 °C in the presence of water. Feed gas composition: 150 ppm C₆H₆, 2.5 vol.% H₂O, air balance. GHSV = 100,000 h⁻¹.

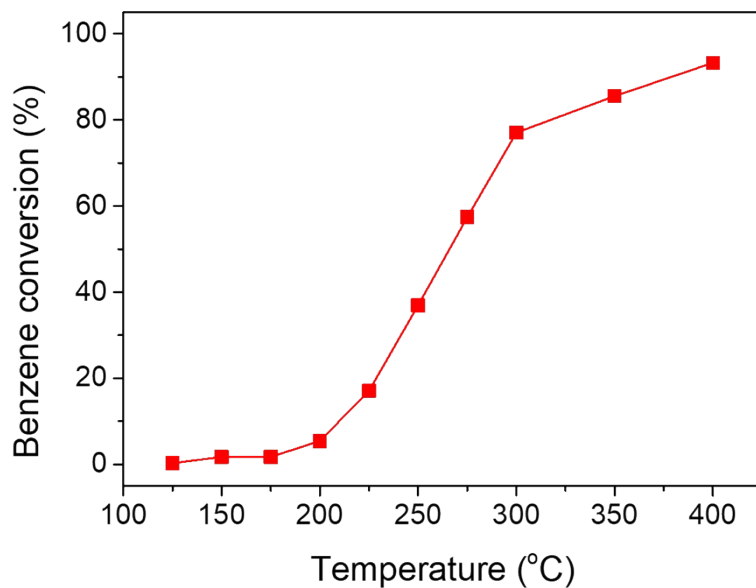


Fig. S6 Light-off curve for benzene oxidation obtained from the CZCuAg (CZ:Cu:Ag = 1:0.5:0.5) catalyst thermally aged at 800 °C for 5 h in air. Feed gas composition: 150 ppm C₆H₆, 5.0 vol.% H₂O, air balance. GHSV = 100,000 h⁻¹.

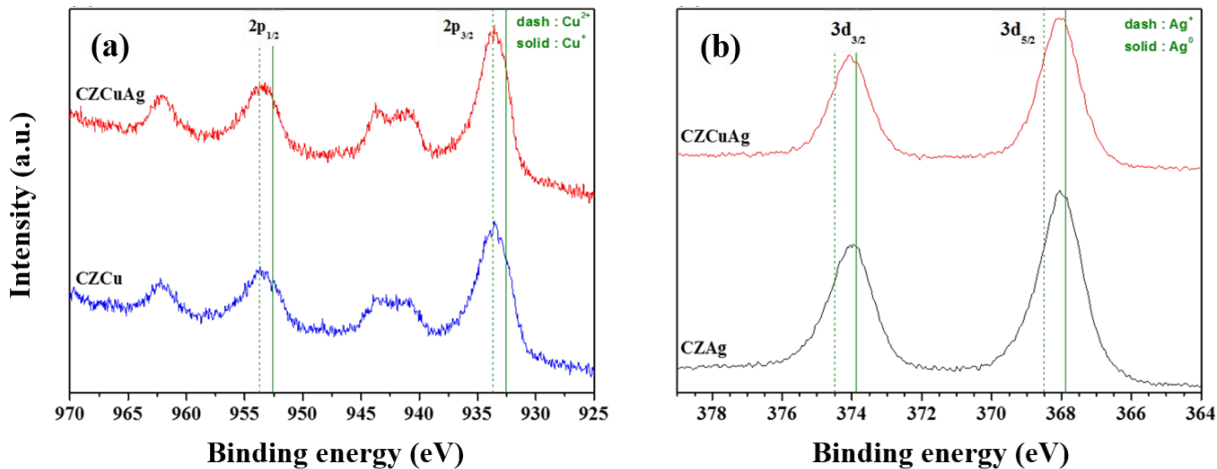


Fig. S7 (a) Cu 2p XPS spectra of CZCu (CZ:Cu = 1:1) and CZCuAg (CZ:Cu:Ag = 1:0.5:0.5) and (b) Ag 3d spectra of CZAg (CZ:Ag = 1:1) and CZCuAg (CZ:Cu:Ag = 1:0.5:0.5).

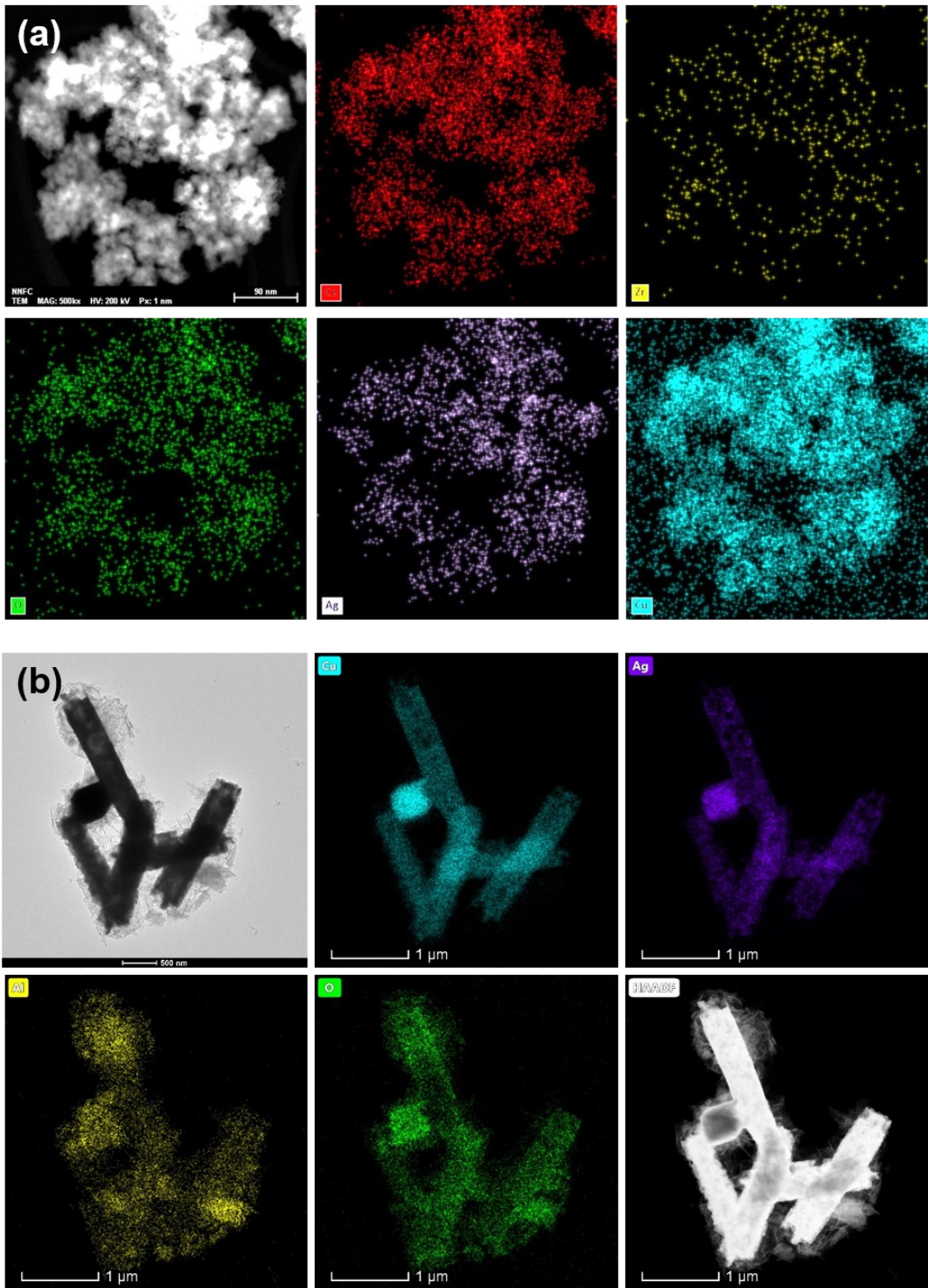


Fig. S8 STEM image and cerium, zirconium, oxygen, silver, copper, and/or aluminum EDX elemental mapping of (a) CZCuAg (CZ:Cu:Ag = 1:0.5:0.5) and (b) CuAg/ γ -Al₂O₃.

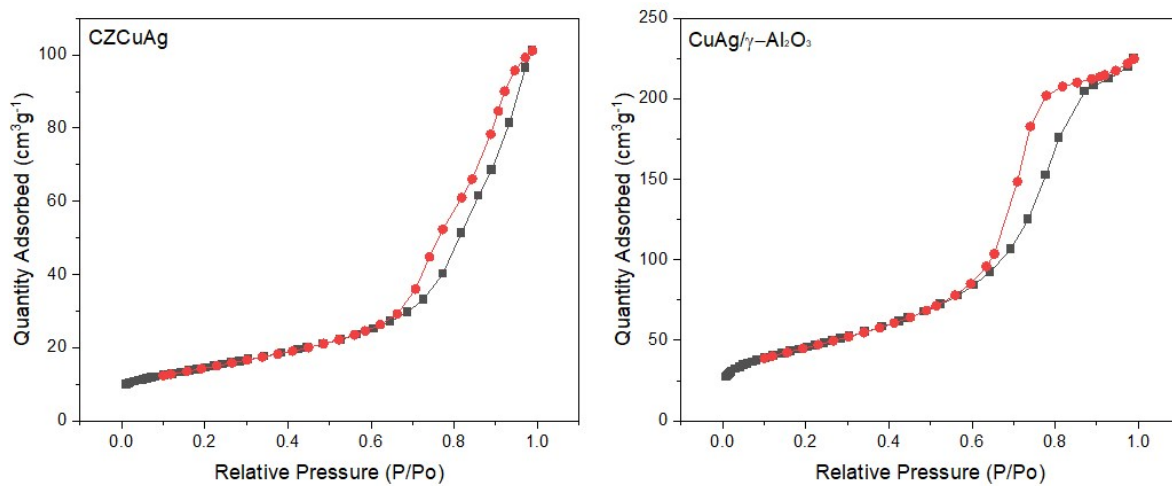


Fig. S9 N₂-physorption isotherms for CZCuAg (CZ:Cu:Ag = 1:0.5:0.5) and CuAg/γ-Al₂O₃.

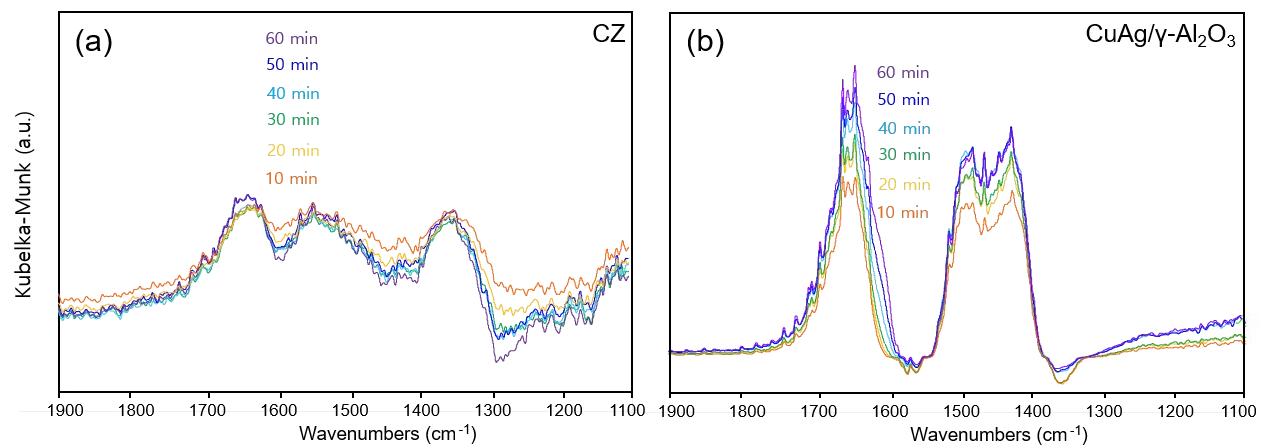


Fig. S10 DRIFT spectra during the benzene oxidation at RT over (a) support CZ and (b) CuAg/ γ -Al₂O₃. Each sample was pretreated with 10% O₂/N₂ at 400 °C for 1 h and 150 ppm of benzene/N₂ was introduced at RT. The spectra were collected every 10 min.

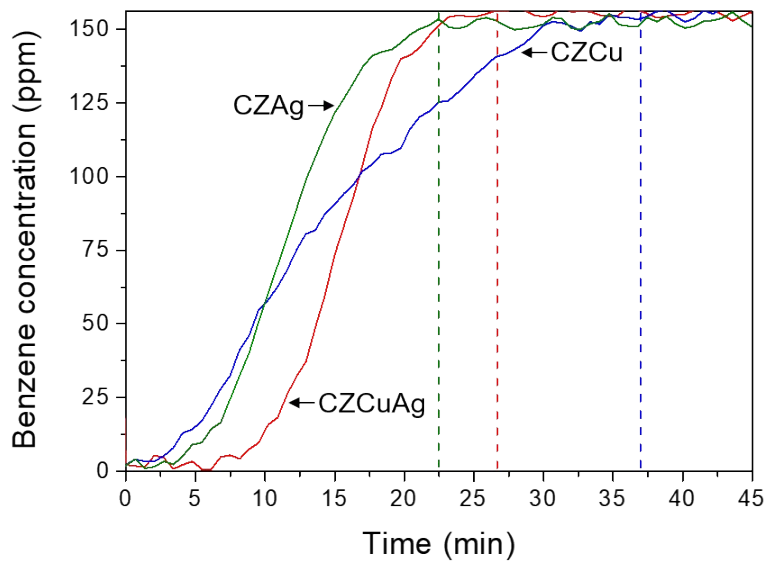


Fig. S11 Benzene adsorption curves at RT for CZCu, CZAg and CZCuAg catalysts. 150 ppm of benzene/air was introduced with GHSV of 100,000 h⁻¹.