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Outstanding Thesis Awards

Physical Science Section | Master Degree Program

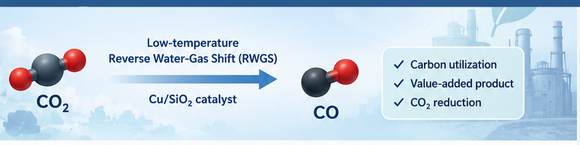
Miss Khrongkhwan Doungdej | Major in Chemical Engineering

Hydroxyethyl Cellulose as a Template for Porous Silica Supports in Copper-Catalyzed Reverse Water-Gas Shift Reaction

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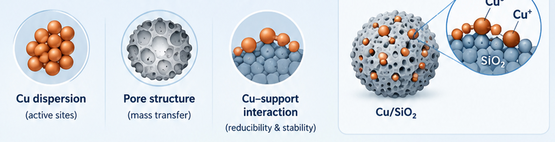
Abstract



The Reverse Water-Gas Shift (RWGS) reaction is an important route for converting CO_2 into CO, a key building block for carbon utilization. Cu/SiO_2 catalysts are attractive because of their low cost and tunable silica support; however, their catalytic performance strongly depends on **Cu dispersion**, **pore structure**, and **Cu–support interactions**.

Challenge

Cu/SiO_2 performance depends on

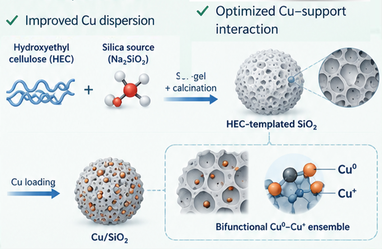


Strategy

HEC-templated SiO_2

- ✓ Tailored pore structure
- ✓ Improved Cu dispersion
- ✓ Optimized Cu–support interaction





This study aims

to tune the Cu–support interaction through HEC-templated silica for enhanced low-temperature RWGS catalysis.

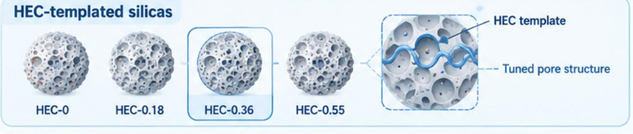
Experimental

1 HEC-templated SiO_2 preparation

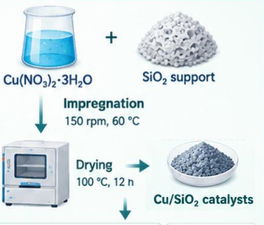
HEC/SiO_2 = 0, 0.18, 0.36, 0.55



HEC-templated silicas



2 Cu loading



Catalyst series (10 wt% Cu)

- 10Cu-HEC-0
- 10Cu-HEC-0.18
- 10Cu-HEC-0.36
- 10Cu-HEC-0.55

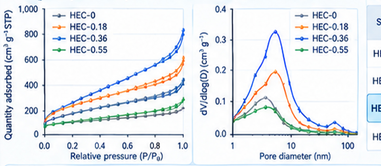
HEC-0.36 Cu loading :

- 5%
- 10%
- 15%

Results & Discussion

1 HEC creates hierarchical porosity in SiO_2

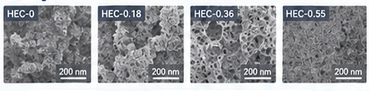
HEC/SiO_2 = 0, 0.18, 0.36, 0.55



Textural properties

Sample	Surface area ($m^2\ g^{-1}$)	Pore volume ($cm^3\ g^{-1}$)	Avg. pore size (nm)
HEC-0	642	0.42	8.5
HEC-0.18	718	0.47	9.8
HEC-0.36	**756**	**0.49**	**11.2**
HEC-0.55	603	0.37	7.6

SEM images

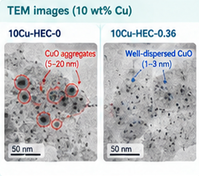


- ✓ HEC templating created a hierarchical porous SiO_2 structure while maintaining high surface area.
- ✓ HEC/SiO_2 = 0.36 provided the most favorable hierarchical pore structure.
- ✓ At 0.55, phase separation occurred, resulting in a lower surface area.

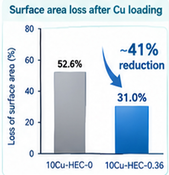
Key message: HEC/SiO_2 = 0.36 → optimal hierarchical porosity

2 Hierarchical porosity improves Cu dispersion

TEM images (10 wt% Cu)



Surface area loss after Cu loading

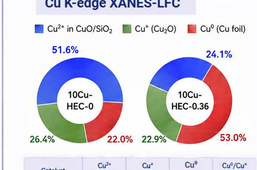


- ✓ Without HEC, CuO formed larger aggregates (≈5–20 nm), leading to significant pore blockage.
- ✓ HEC-0.36 promoted finely dispersed CuO nanoparticles (≈1–3 nm) with reduced pore blockage.

Key message: The hierarchical pore network provides better accessibility for Cu species and suppresses CuO aggregation.

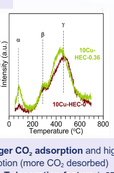
3 HEC tunes the Cu–O–Si interface and Cu oxidation state

Cu K-edge XANES-LFC



Catalyst	Cu^{2+} (%)	Cu^{+} (%)	Cu^{0} (%)	Cu^{0}/Cu^{+} ratio
10Cu-HEC-0	51.6	26.4	22.0	0.83
10Cu-HEC-0.36	24.1	22.9	53.0	2.31

CO_2 TPD

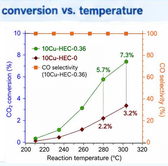


- ✓ **Stronger CO_2 adsorption** and higher desorption (more CO_2 desorbed)
- ✓ **Lower-T desorption feature** (~87-98 C) enhanced (weaker, more activated CO_2)
- ✓ **Higher desorption intensity** (more available reactive oxygen sites)

Key message: HEC tunes the Cu–O–Si interface and promotes a reduced, well-dispersed Cu surface.

4 Hierarchical porosity and tuned Cu species enhance low-temperature RWGS performance

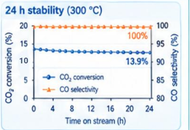
CO_2 conversion vs. temperature



Reaction conditions

- 1 bar
- H_2/CO_2 = 3
- GHSV = 10,800 mL g^{-1} h^{-1}
- 100% CO selectivity

24 h stability (300 °C)



At 300 °C, 1 bar, H_2/CO_2 = 3, GHSV 10,800 mL g^{-1} h^{-1} :

10Cu-HEC-0.36 achieved **7.3%** CO_2 conversion | **10Cu-HEC-0** gave **3.2%**

Key message: Hierarchical porosity and tuned Cu species translate into higher low-temperature RWGS activity and excellent stability.

Conclusion

HEC templating at an optimal HEC/SiO_2 ratio of 0.36 improved pore preservation and Cu dispersion. The 10Cu-HEC-0.36 catalyst achieved 100% CO selectivity with 7.3% CO_2 conversion at 300 °C and showed excellent 24-h stability. The enhanced performance is attributed to the optimized Cu^0/Cu^+ bifunctional active sites that promote H_2 dissociation and CO_2 activation.

Acknowledgement

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Thesis Book File