

Supporting Information

**Achiral copper clusters helically confined in self-assembled chiral  
nanotubes emitting circularly polarized phosphorescence**

Ya-Jie Wang<sup>a</sup>, Yan Jin<sup>a</sup>, Xiao-Yan Shi<sup>a</sup>, Xi-Yan Dong<sup>a,b,\*</sup> and Shuang-Quan Zang<sup>a,\*</sup>

<sup>a</sup> College of Chemistry, Zhengzhou University, Zhengzhou 450001, China.

<sup>b</sup> College of Chemistry and Chemical Engineering, Henan Polytechnic University,  
Jiaozuo 454000, China.

## Experimental Section

### Materials

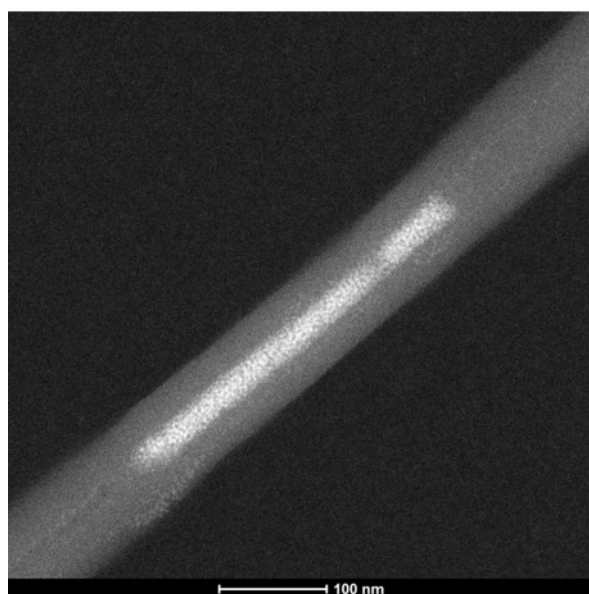
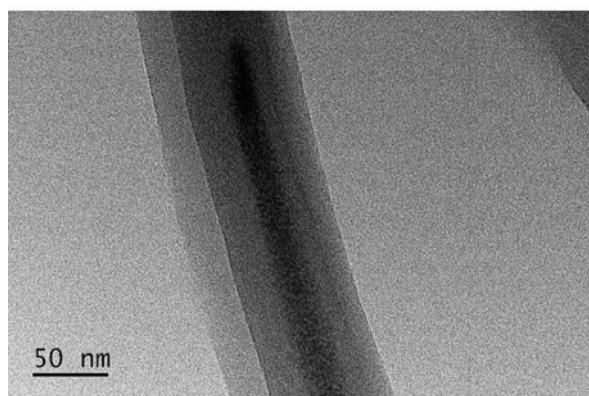
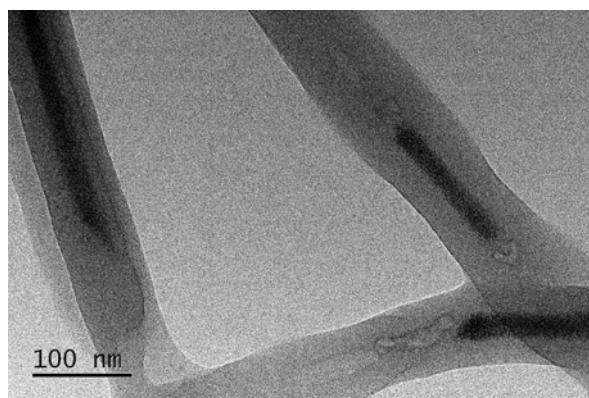
All starting materials and solvents were purchased from commercial suppliers and used without any further purifications. Gelator D/L-G<sup>+</sup> was synthesized according to literature.<sup>1, 2</sup> Cu<sub>5</sub><sup>-</sup> clusters were synthesized according to literature.<sup>3</sup>

### Characterizations

Scanning electron microscopy (SEM) was carried out by a field-emission Zeiss Sigma 500. Samples for SEM were prepared by dropping about 5-10  $\mu$ L of assemblies on the polished silicon wafer, followed by air dried. Before the characterization, an Au spray was performed on the samples to enhance the contrast. Transmission electron microscopy (TEM) images were obtained on FEI TalosF200S equipment. Electrospray ionization mass spectrometry (ESI-MS) was performed on an AB Sciex X500R Q-TOF spectrometer. Ultraviolet-visible (UV-vis) absorption spectra were recorded on a Hitachi UH4150 UV-visible spectrophotometer. Steady-state photoluminescence (PL) spectra were obtained *via* a HORIBA FluoroLog-3 fluorescence spectrometer. The luminescence lifetimes were measured on an Edinburgh FLS 980 fluorescence spectrometer operating in time-correlated single-photon counting (TCSPC) mode. Circular dichroism (CD) spectra were measured with a Chirascan V100 spectropolarimeter. Circularly polarized luminescence (CPL) spectra were measured on a JASCO CPL-300 spectrometer.

### Preparation of Cu<sub>5</sub> cogel

Cuprous oxide (5 mg, 0.035 mmol) and D-G<sup>+</sup> (22.75 mg, 0.033 mmol) were mixed in ethanol (0.5 mL). *tert*-butyl mercaptan (0.25 mL, 2.217 mmol) was added to the blood-red mixture under vigorous stirring at 70 °C. Then, ammonia (0.1 mL, 2.597 mmol) was added to the mixture and a faint yellow solution was obtained after several minutes. The solution was subsequently cooled down to room temperature under environmental conditions. Uniform cogel of D-G<sup>+</sup>/Cu<sub>5</sub><sup>-</sup> was obtained. L-G<sup>+</sup>/Cu<sub>5</sub><sup>-</sup> cogel was also fabricated through the same method.



**Fig. S1** TEM and HAADF-TEM images of D-G<sup>+</sup>/Cu<sub>5</sub><sup>-</sup> cogel.

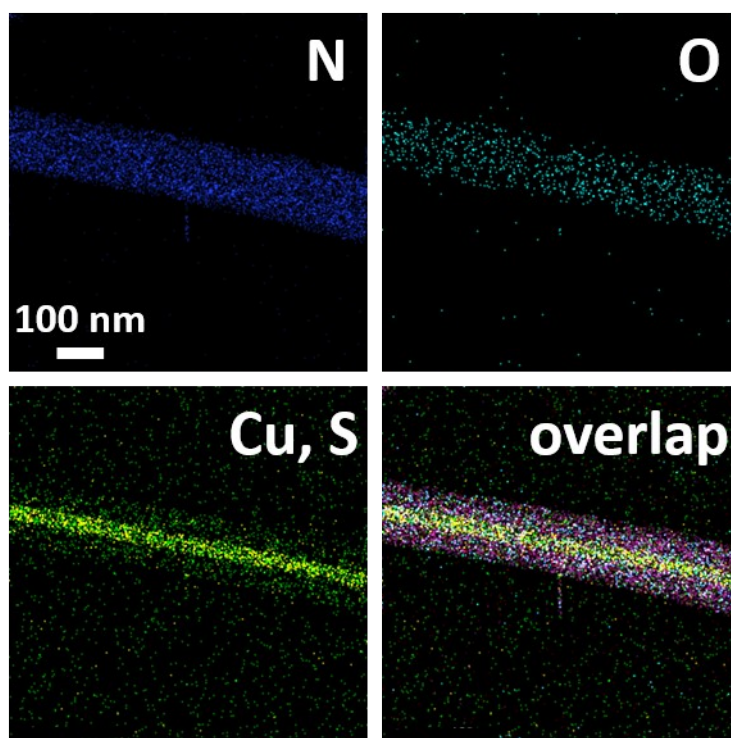


Fig. S2 TEM-EDS elemental mapping of a strand of nanotube containing  $\text{Cu}_5^-$  clusters.

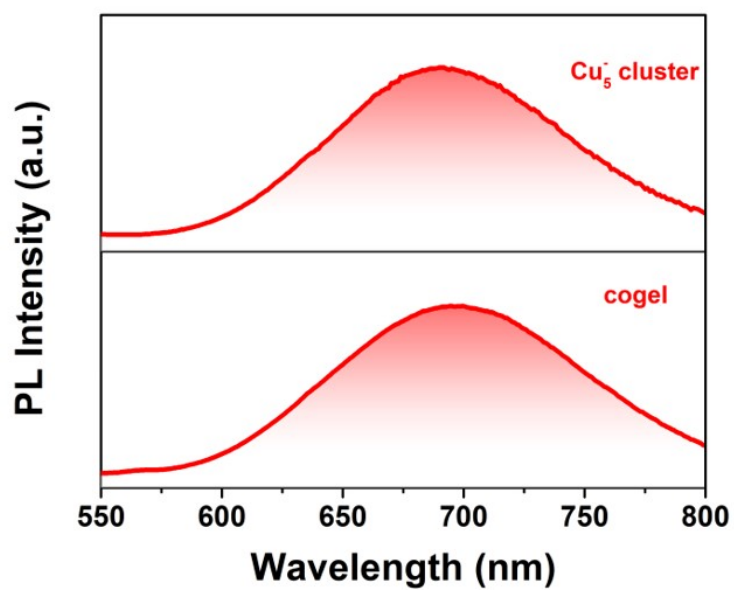
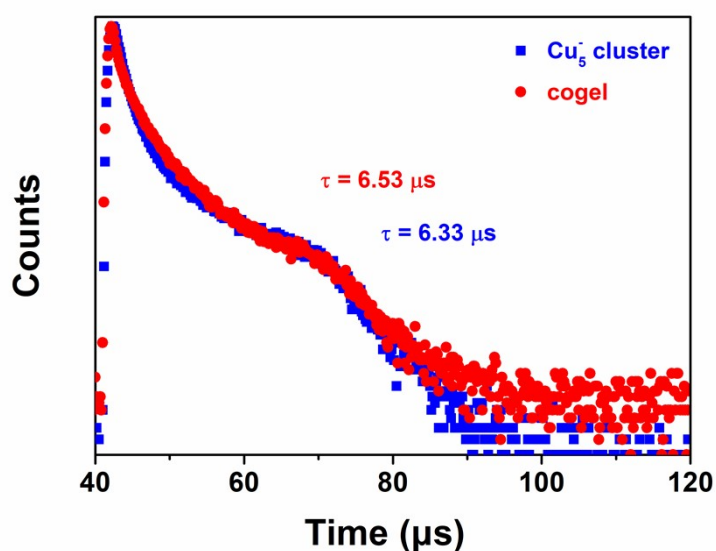
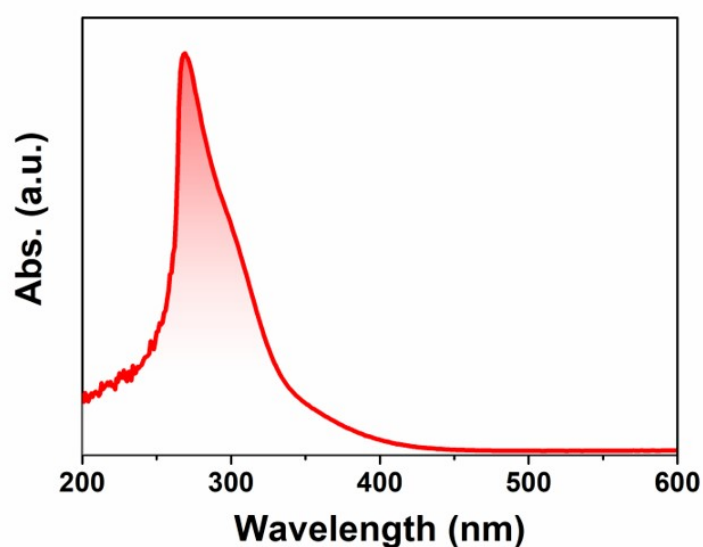


Fig. S3 Photoluminescence spectra of  $\text{Cu}_5^-$  cluster in DMSO solution under  $\text{N}_2$  atmospheres (up) and D-G<sup>+</sup>/ $\text{Cu}_5^-$  cogel (down).



**Fig. S4** Time resolved emission of  $\text{Cu}_5^-$  clusters in DMSO solution under  $\text{N}_2$  atmospheres (blue square) and D-G<sup>+</sup>/ $\text{Cu}_5^-$  cogel (red circle).

In Fig. S5, the lifetimes consist of two parts. For the lifetime of  $\text{Cu}_5^-$  clusters in solution state, the first part ( $T_1$ ) is 1.33  $\mu\text{s}$  accounting for 34.35% and the second part ( $T_2$ ) is 9.35  $\mu\text{s}$  for 62.84%, contributing to the total lifetime of 6.33  $\mu\text{s}$ . The same as the lifetime of in cogel state, the first part ( $T_1$ ) is 2.00  $\mu\text{s}$  accounting for 27.18% and the second part ( $T_2$ ) is 9.30  $\mu\text{s}$  for 64.42%, contributing to the total lifetime of 6.53  $\mu\text{s}$ .



**Fig. S5** UV-vis absorption spectrum of  $\text{Cu}_5^-$  solutions obtained from extracting the cogels.

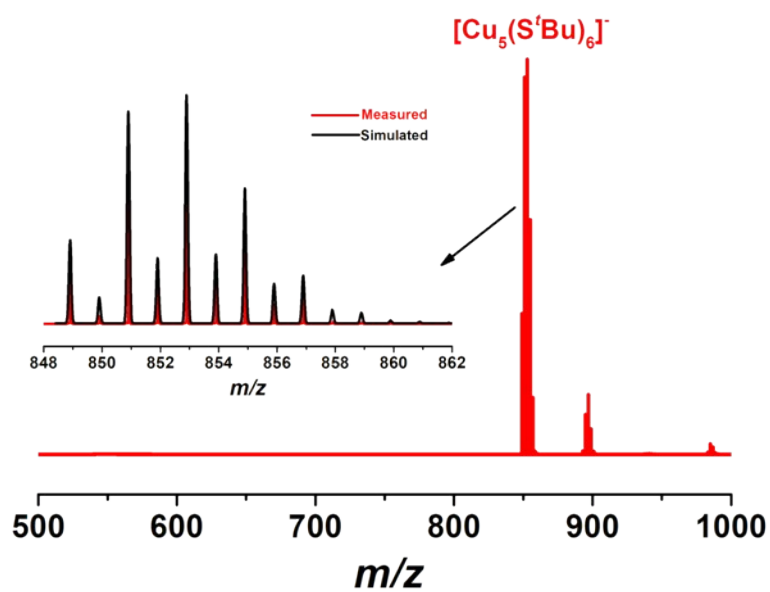


Fig. S6 ESI-MS spectrum of  $\text{Cu}_5^-$  solutions obtained from extracting the cogels.

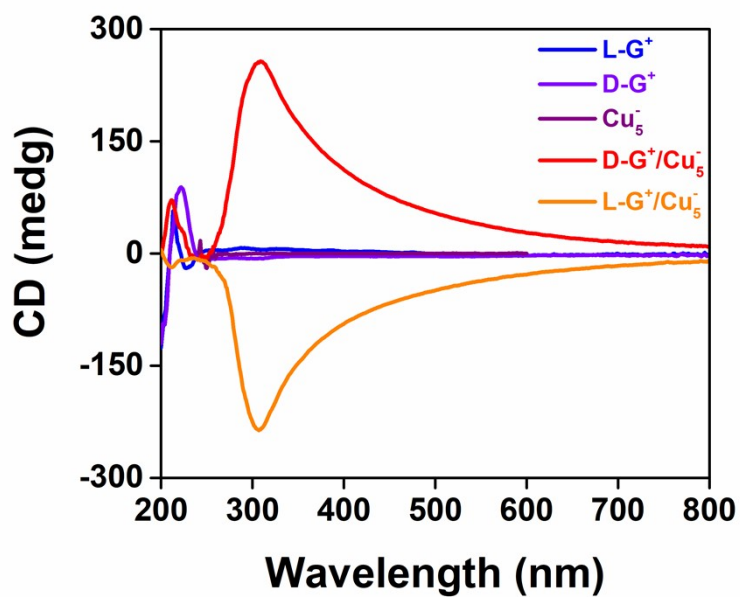


Fig. S7 CD spectra of cogels, D/L- $\text{G}^+$  gelators and  $\text{Cu}_5^-$  clusters.

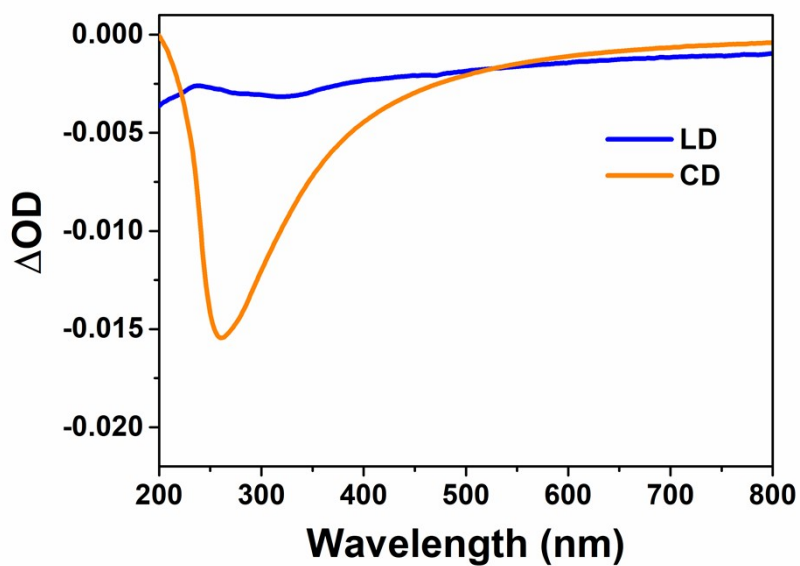


Fig. S8 Linear dichroism spectrum and CD spectrum comparison of L-G<sup>+</sup>/Cu<sub>5</sub><sup>-</sup> cogel.

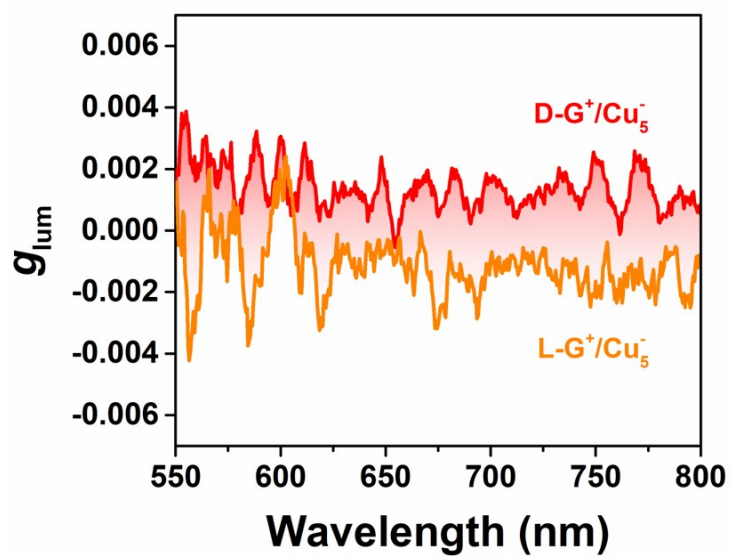
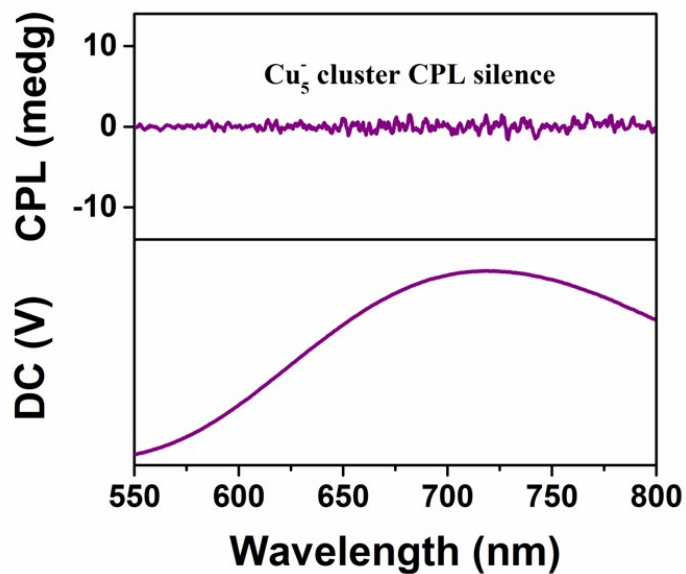
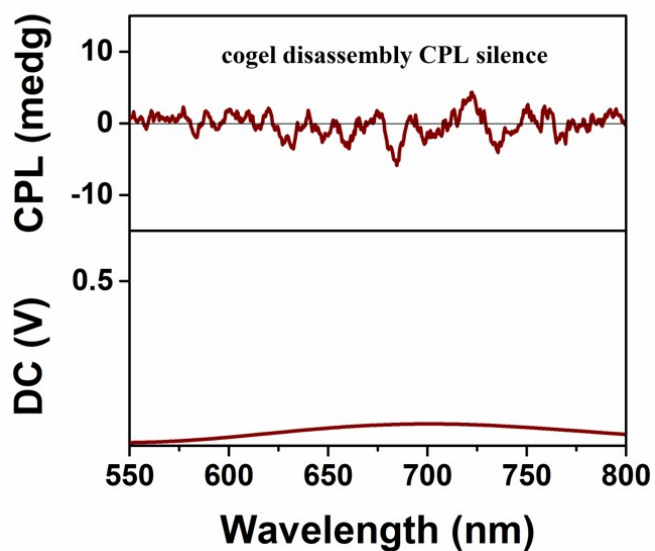


Fig. S9 Corresponding g<sub>lum</sub> values of Cu<sub>5</sub><sup>-</sup> cluster and gelators cogels.



**Fig. S10** CPL spectrum of Cu<sub>5</sub><sup>-</sup> cluster in DMSO solution under N<sub>2</sub> atmospheres.



**Fig. S11** CPL spectrum of disassembled mixture of Cu<sub>5</sub><sup>-</sup> cluster and chiral gelator L-G<sup>+</sup> in chlorobenzene solution.



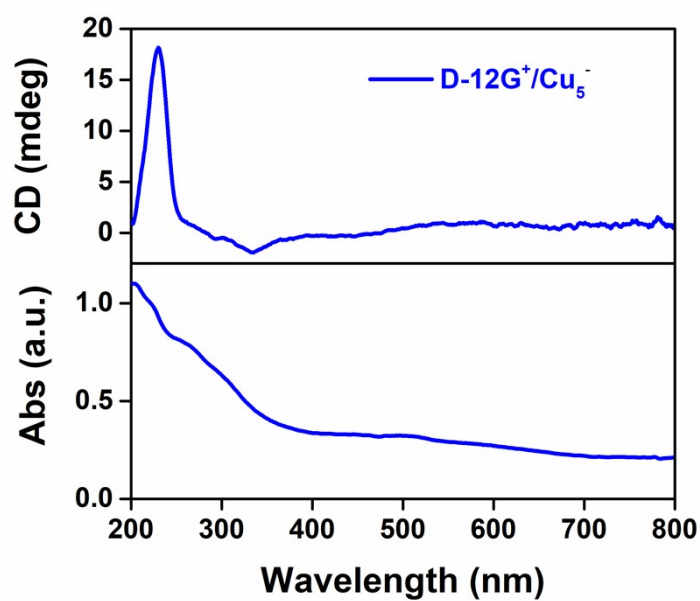


Fig. S12 CD spectrum of D-12G<sup>+</sup>/Cu<sub>5</sub><sup>-</sup> cogel.

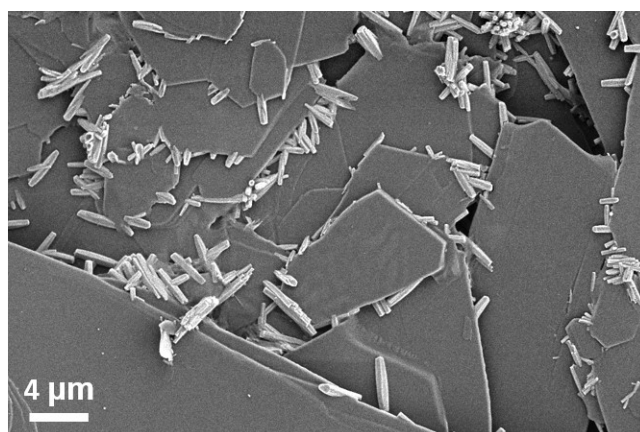


Fig. S13 SEM images of D-12G<sup>+</sup>/Cu<sub>5</sub><sup>-</sup> cogel.

## Reference

1. T. Goto, Y. Okazaki, M. Ueki, Y. Kuwahara, M. Takafuji, R. Oda and H. Ihara, *Angew. Chem. Int. Ed.*, 2017, **56**, 2989-2993.
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