

Electronic Supplementary Information

Ratiometric fluorescent paper sensor utilizing hybrid carbon dots-quantum dots for the visual determination of copper ions

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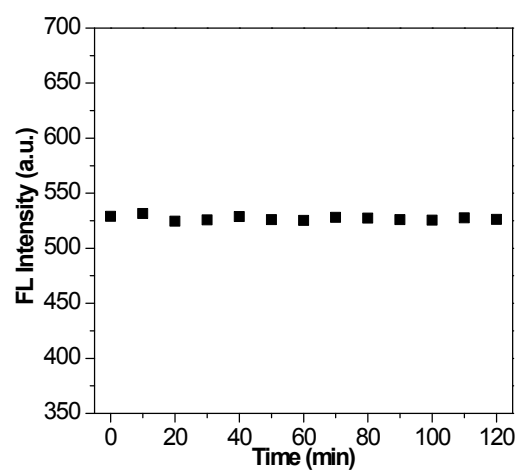


Figure S1. Stability of the fluorescence intensity of CDs in 2 h.

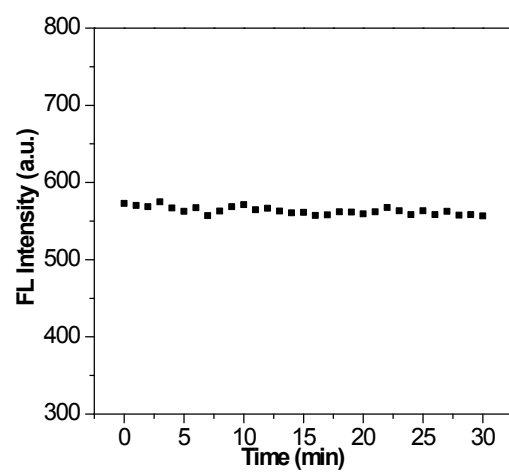


Figure S2. Time course of CDs in the presence of 200 nM Cu²⁺ in 30 min.

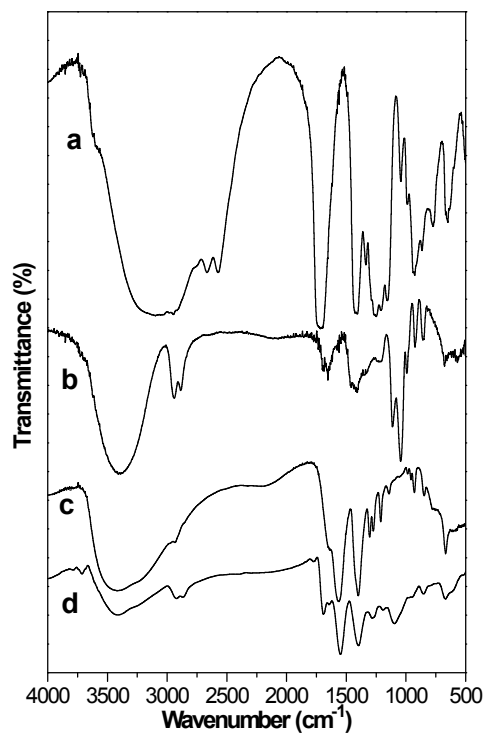


Figure S3. The FT-IR spectra of (a) 3-mercaptopropionic acid (MPA), (b) MPA capped CdTe QDs, (c) amine-coated CDs and (d) ratiometric fluorescence probe.

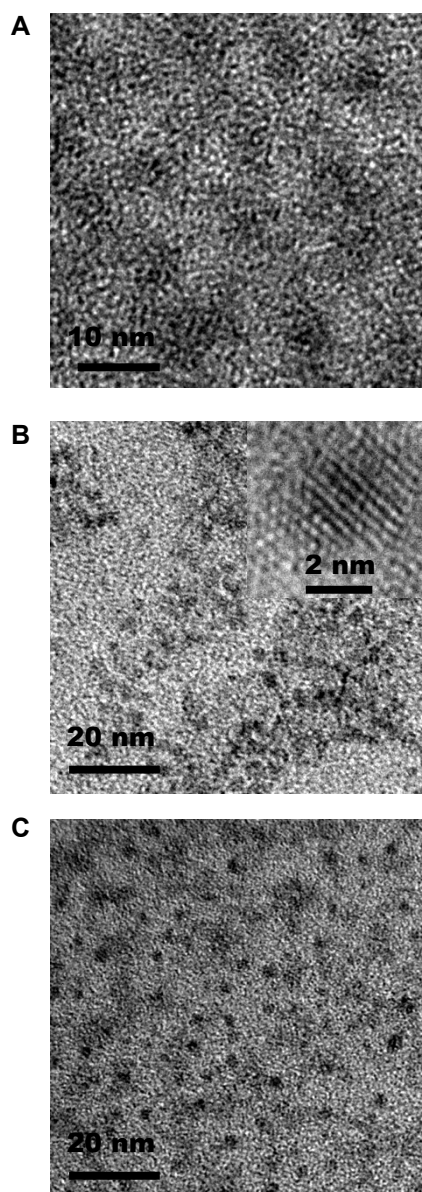


Figure S4. TEM images of (A) the blue CDs, (B) the red QDs (inset: the corresponding HR-TEM image) and (C) the ratiometric fluorescence probe.

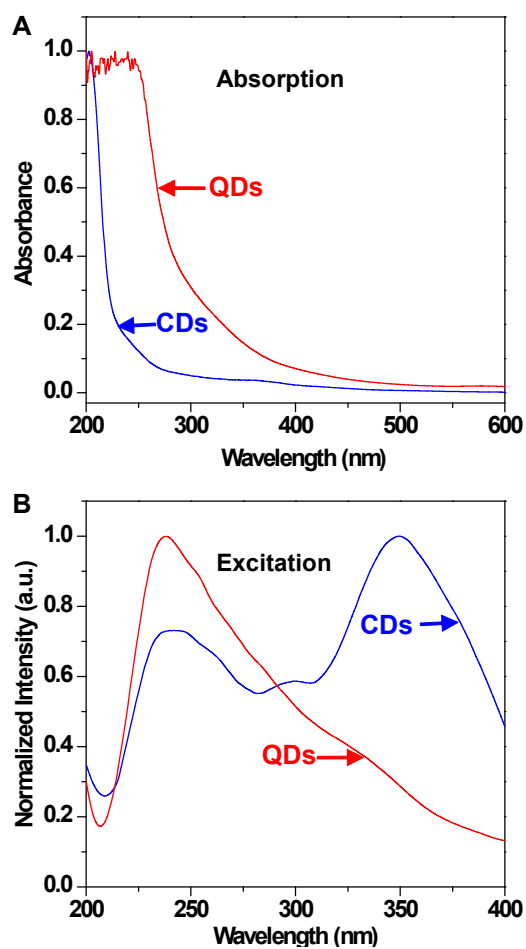


Figure S5. (A) The absorption spectra of blue-emission CDs and red-emission MPA–CdTe QDs. (B) The fluorescence excitation spectra of blue-emission CDs ($E_m=440$ nm) and red-emission MPA–CdTe QDs ($E_m=654$ nm).

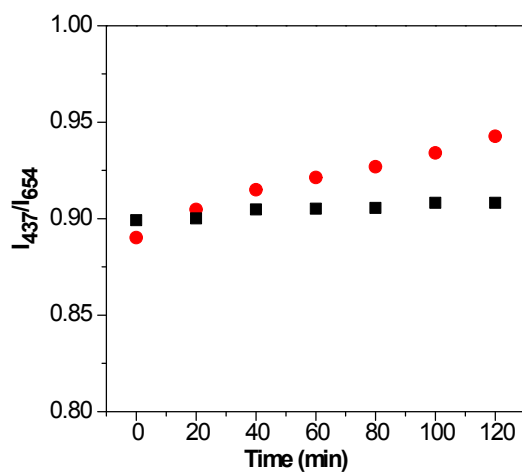


Figure S6. Stability of the fluorescence intensity ratio (I_{437}/I_{654}) of the nanohybrid probe (black square) and the simple mixed of QDs and CDs (red circles), respectively.

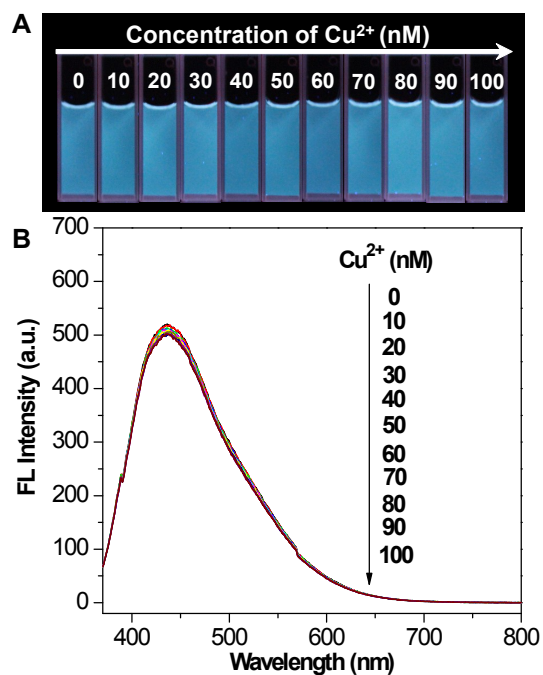


Figure S7. (A) The fluorescence image set and (B) the corresponding fluorescence spectra ($\lambda_{\text{ex}}=340$ nm) of the blue CDs upon the addition of different concentrations of Cu^{2+} .

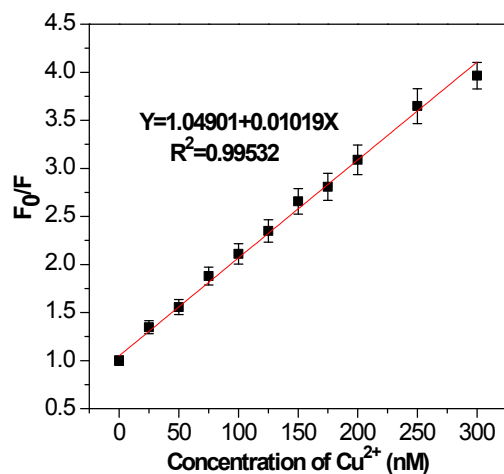


Figure S8. Plot of the fluorescence intensity change (F_0/F) of the red MPA-CdTe QDs as a function of the concentrations of Cu^{2+} ($\lambda_{\text{ex}}=340$ nm).

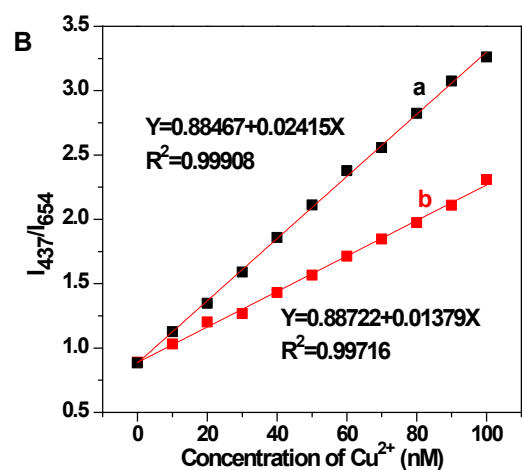
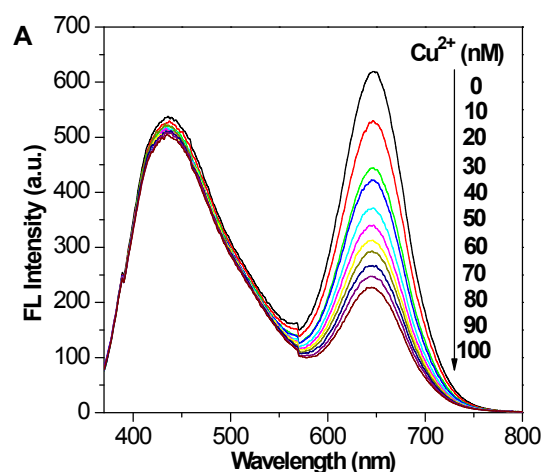


Figure S9. (A) The fluorescence spectra of the simple mixed of MPA-CdTe QDs and CDs upon the addition of different concentrations of Cu²⁺. (B) Changes in the fluorescence intensity ratio (I_{437}/I_{654}) of (a) the ratiometric probe and (b) the mixture of CDs and MPA-CdTe QDs exposure to different concentrations of Cu²⁺.

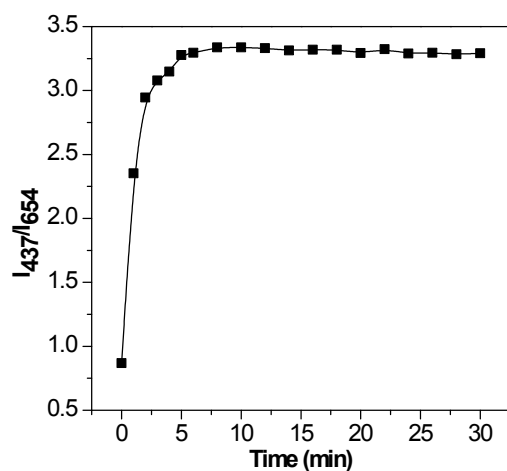


Figure S10. The kinetics of fluorescence quenching. The fluorescence quenching ratio (I_{437}/I_{654}) of the ratiometric fluorescence probe via time with the addition of 100 nM Cu²⁺.

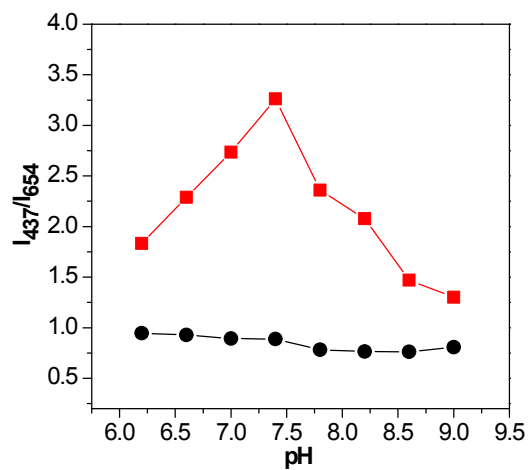


Figure S11. Effect of pH on the fluorescence intensity ratio (I_{437}/I_{654}) of the ratiometric probe in the absence (black line) and presence (red line) of 100 nM Cu^{2+} .

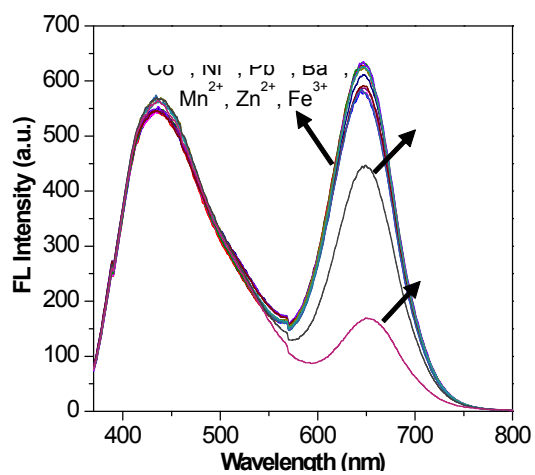


Figure S12. Fluorescence responses of the ratiometric probe towards various metal ions in the HEPES buffer (10 mM, pH=7.4). The concentrations of metal ions are 100 nM.

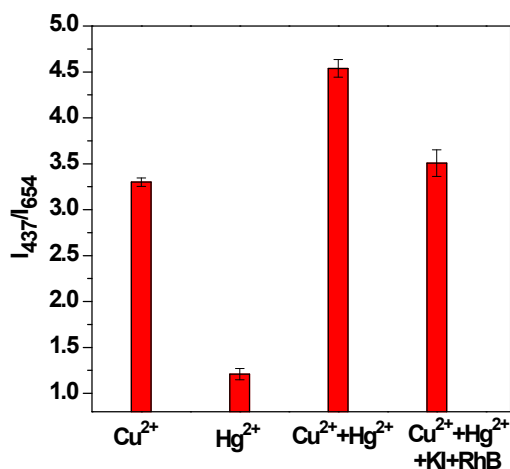


Figure S13. Fluorescence responses of the ratiometric probe towards 100 nM of Cu^{2+} , Hg^{2+} , the mixture of Cu^{2+} and Hg^{2+} , the pretreated mixture of Cu^{2+} and Hg^{2+} .

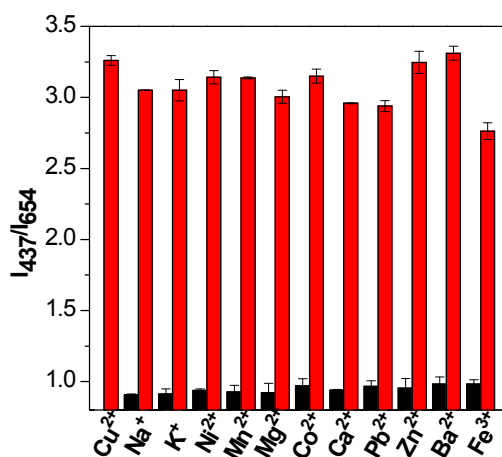


Figure S14. The interference studies of the nanohybrid probe toward Cu^{2+} . Fluorescence responses of the ratiometric probe towards various metal ions in HEPES buffer(10 mM, pH=7.4). The black bars represent the addition of an excess of cations (1 μM) in the absence of copper ions. The red bars represent the subsequent addition of 100 nM Cu^{2+} to the above solution.

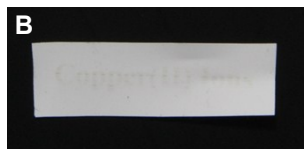


Figure S15. Images of (A) the prepared nanohybrid dispersed in water and (B) the paper-based test strip under daylight.

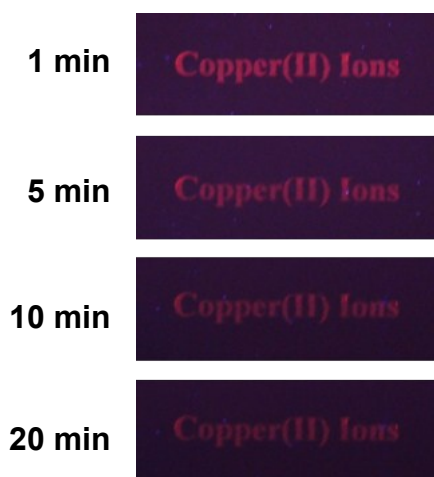


Figure S16. Stability of the fluorescence of the printed pattern “Copper(II)” immersed in water within 20 minutes.