Supplementary Information

High luminescent N,S,P co-doped carbon dots for the fluorescence sensing of extreme acidity and folic acid

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Optimization of synthesis conditions

m-Phenylenediamine (MPD), L-cysteine and H_3PO_4 were selected as raw materials to synthesize N,S,P heteroatom co-doped CDs. It is well known that the fluorescence quantum yield (QY) of N,S,P-CDs was affected by the ratio of precursors, reaction temperature and reaction time[1]. Therefore, the synthesis conditions were optimized to improve the QY of N,S,P-CDs. Firstly, the amount of m-phenylenediamine was controlled to be 0.1 g, and the molar ratios of L-cysteine to H_3PO_4 varied from 1:1 to 5:1 (1:1,1:3,1:5,3:1,5:1). The QY of the as-synthesized N,S,P-CDs were measured respectively, and the results are shown in Table S1. The QY is the highest when the molar ratio of L-cysteine to H_3PO_4 is 1:3, indicating that excessive doping is not conducive to the improvement of QY. This may be related to the excessive heteroatomic elements blocking the passivated surface defects, resulting in the decrease of QY[2]. Next, the synthesis temperature and time of N,S,P-CDs were optimized (Fig. S1a). The results revealed that with the increase of temperature, QY firstly increases and then decreases, and reaches the maximum at 180 °C. The decrease at higher temperatures indicates that high temperature oxidation may affect QY[3]. Subsequently, the synthesis time was investigated and the reaction time of 9 h was determined to be the most favorable (Fig. S1b). Prolonged reaction may cause excessive carbonization of carbon dots to form byproducts[4]. In general, the optimal synthesis conditions of N,S,P-CDs were 180 °C, 9 h, and the molar ratio of L-cysteine to H_3PO_4 was 1:3.

References

[1]. L. P. Sun, H. Y. Chen, Y. Wang, C. X. Wang, L. F. Dong, RSC Adv, 2016, 6, 91225.

[2]. Y. Luo, M. Li, L. Sun, Y. J. Xu, M. Li, G. H. Hu, T. Tang, J. F. Wen, X, Y, Li, J. Y. Zhang, L. Wang, Journal of Colloid and Interface Science, 2018, 529, 205-213.

[3]. Q. Xu, B. F. Li, Y. C. Ye, W. Cai, W. J. Li, C. Y. Yang, Y. S. Chen, M. Xu, Nano Research, 2018, 11(7), 3691-3701.

[4]. H.K. Melvin Ng, G.K. Lim, C.P. Leo, Microchemical Journal, 2021, 165, 106116.

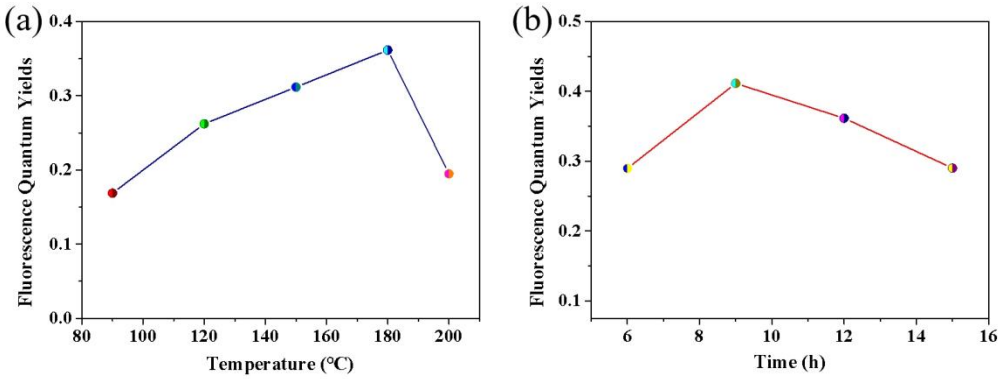

Fig.S1 The relationship between fluorescence quantum yield and synthesis temperature (a) and time (b).

Table S1 The relationship between the ratio of raw materials and the quantum yield.

$n_{L\text{-}cys}$: n_{H3PO4}	1:1	1:3	1:5	3:1	5:1
QY (%)	6.45	36.16	27.19	24.04	25.23

Table S2. Elemental analysis of the N,S,P-CDs

Elemental content (%)					
C	H	O	N	S	P
54.66	7.96	22.89	6.90	3.06	4.53

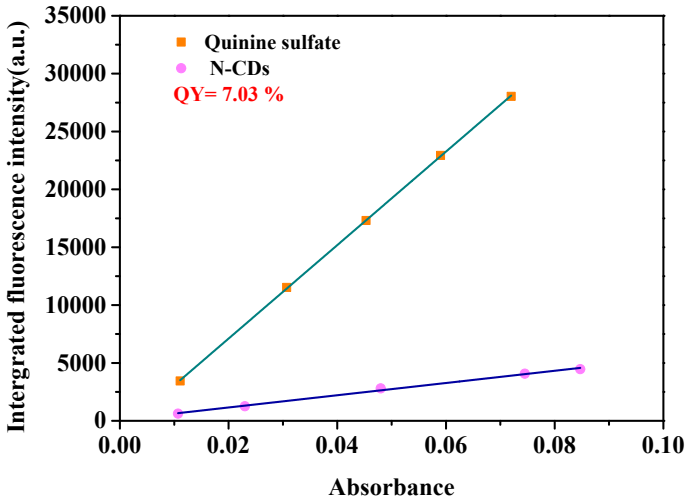

Fig. S2 The measurement of fluorescence quantum yield for N-CDs.

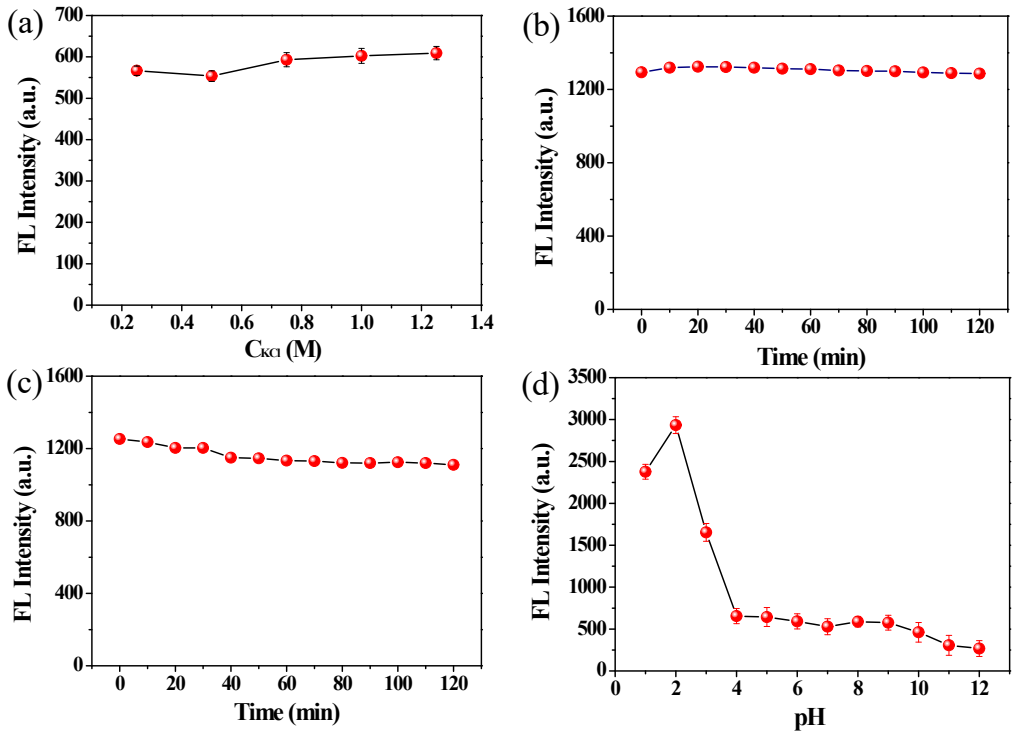

Fig. S3 The fluorescence stability of N,S,P-CDs, including: KCl (a), Xenon lamp irradiation (b), UV irradiation irradiation (c), and pH (d).

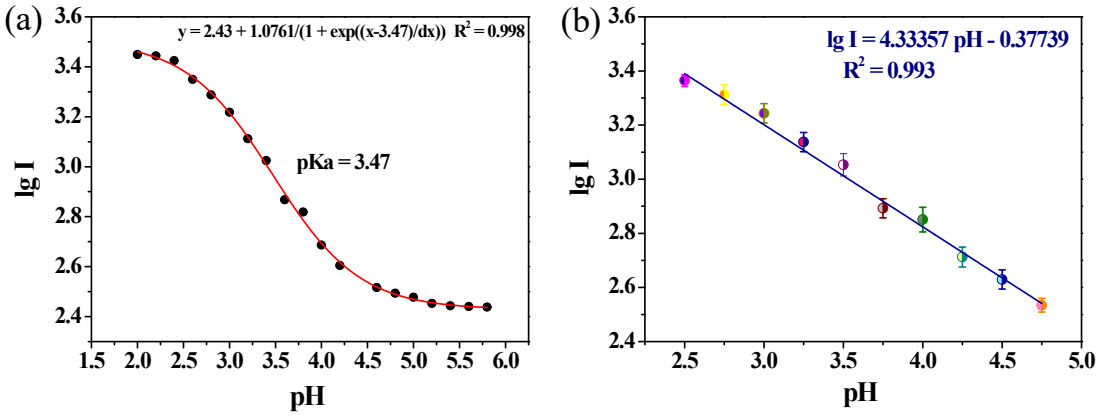

Fig. S4 (a) The fitting curve between the fluorescence intensity of N,S,P-CDs and pH. (b) The linear relationship between pH value and fluorescence intensity of N,S,P-CDs.

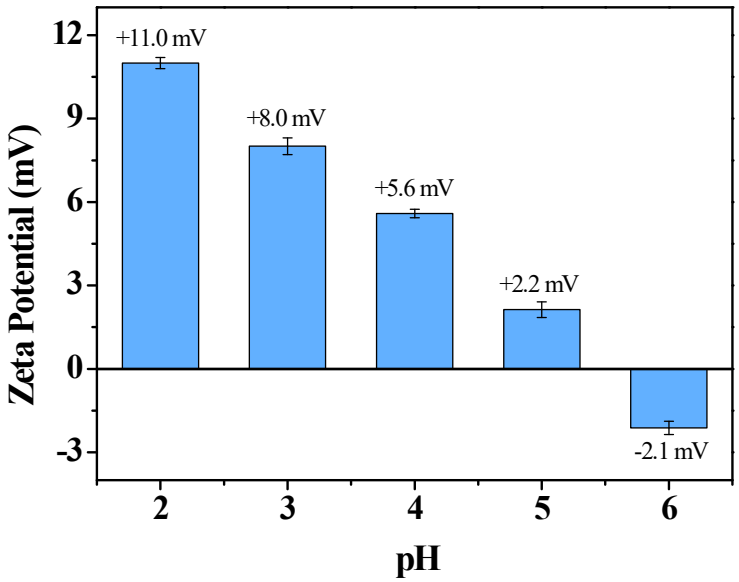

Fig. S5 The Zeta potential of N,S,P-CDs at different pH.

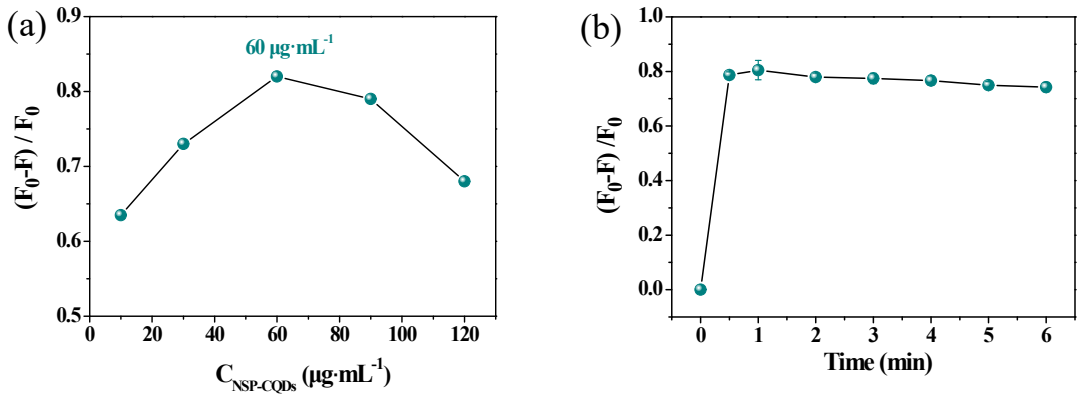

Fig. S6 Optimization of detection conditions for sensing FA, including the concentration of N,S,P-CDs (a) and incubation time (b) .

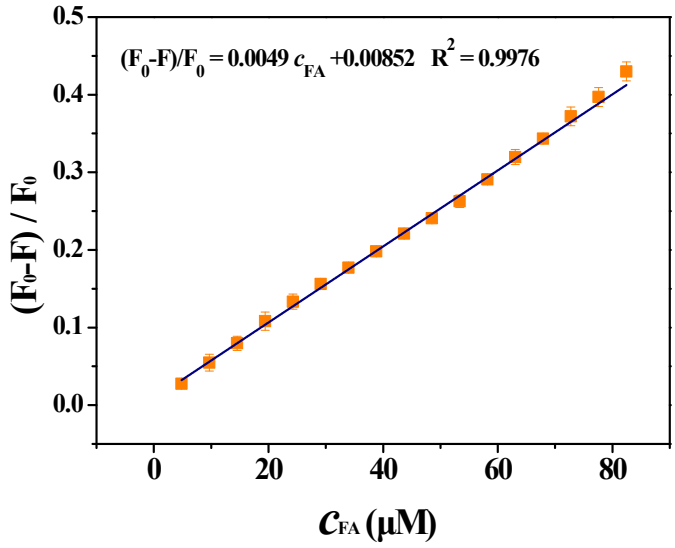

Fig. S7 The linear relationship between N,S,P-CDs and FA in the range of 4.85-82.45 μM.

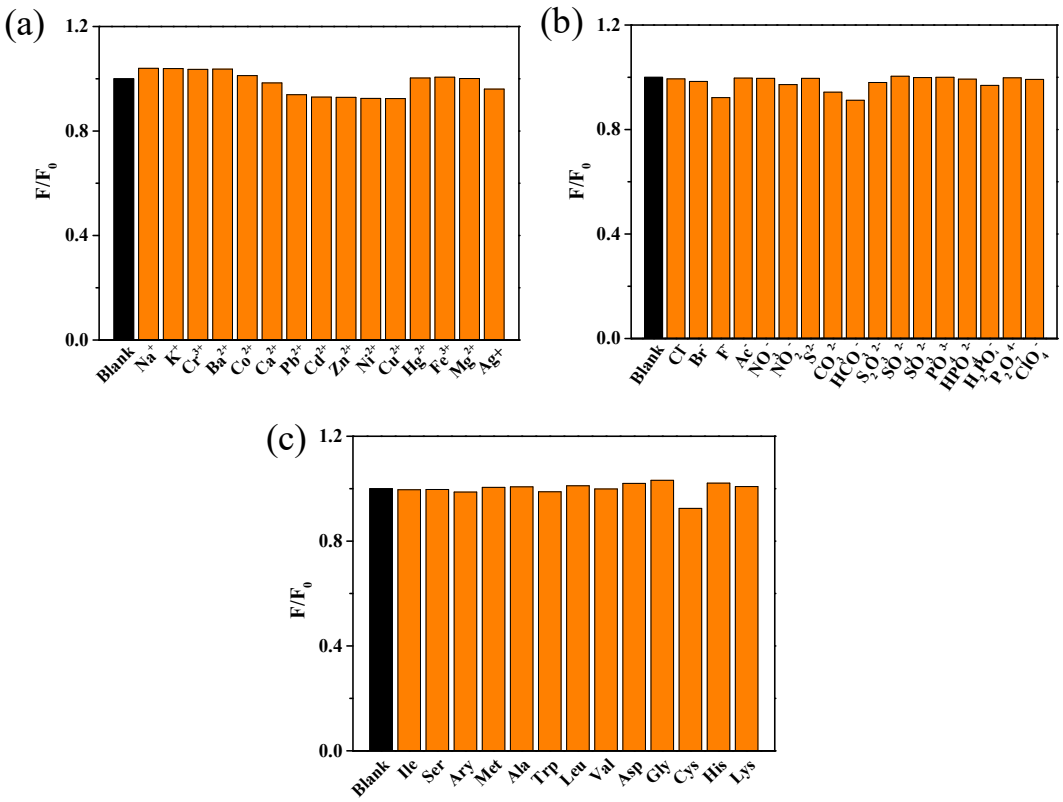

Fig. S8 Interference experiment of metal ions (a) , anions (b) and amino acidons(c) on FA detection by N,S,P-CDs

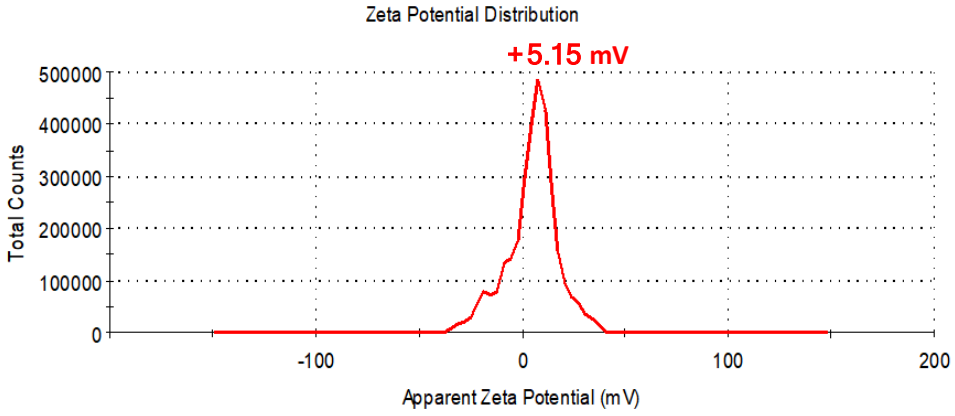

Fig. S9 The Zeta potential of FA at pH 2.

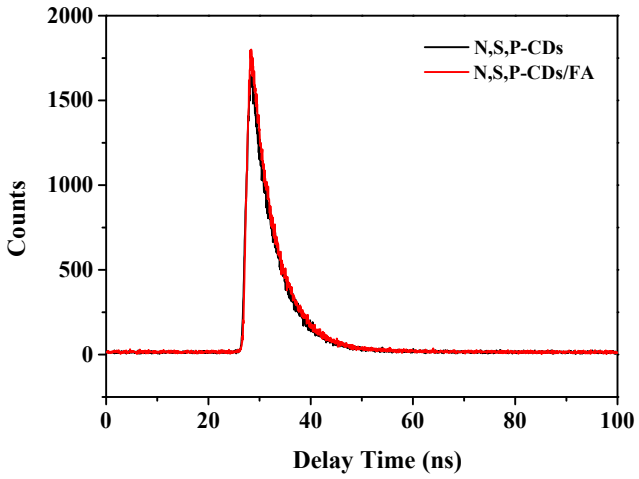

Fig. S10 The fluorescence lifetime of N,S,P-CDs in the presence and absence of FA.