Supporting Information

Diagnosis of penicillin allergy: a MOFs-based composite hydrogel for detecting β-lactamase in serum

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Experimental Section

Materials and Reagents: $Eu(OH)_3$ was prepared from Eu_2O_3 via hydrothermal method. All other reagents and solvents were commercially available and of analytical pure grade. Penicillamine (Pen, 98%) and β-lactamase (10 MU) were purchased from Aladdin.

Synthesis of $[Eu_2(BPDC)(BDC)_2(H_2O)_2]_n$ (1): $[Eu_2(BPDC)(BDC)_2(H_2O)_2]_n$ was synthesized according to the previous literature.[1] Typically, a mixture of $Eu(OH)_3$, H_2bpydc (2,2' bipyridine-3,3'-dicarboxylic acid, Adamas-beta, 97%), H_2bdc (1,4-benzenedicarboxylic acid, Lancaster Synthesis, 98%) and H_2O with a molar ratio of 0.4: 0.6: 0.3: 0.56 was added into a polytetrafluoroethylene-lined steel autoclave. The autoclave was heated at 433 K for 72 h and then slowly cooled down to room temperature. The product was collected with centrifugation and washed with DI water several times.

Synthesis of nanoscale $[Eu_2(BPDC)(BDC)_2(H_2O)_2]_n$ (1): $Eu(OH)_3$ (0.162g, 0.8 mmol), H_2bpydc (0.2932g, 1.2mmol), H_2bdc (0.0998g, 0.6mmol) and AcONa (0.4 mmol, Greagent, 99%) were dispersed in H_2O (20 mL), transfer into a 50 mL autoclave after stirring for 20 min. The autoclave was heated at 433 K for 72 h and then naturally cooled down to room temperature. The product was collected with centrifugation and washed with DI water.

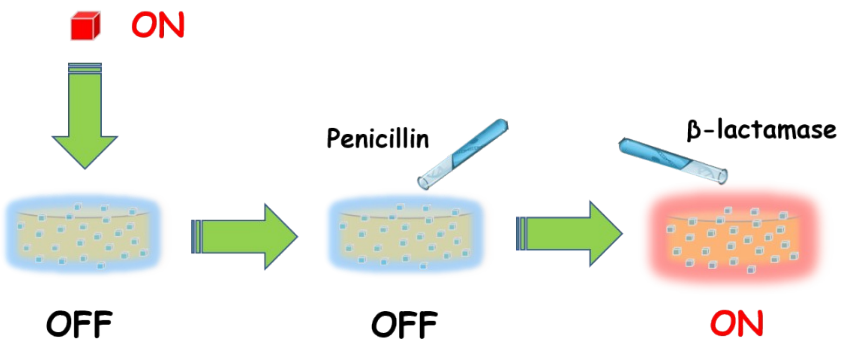
Preparation of 1@SA composite hydrogel: The homogenous suspension (A) of nanoscale **1** powder was prepared in deionized water ultrasonically. The sodium alginate solution

(B) was obtained by dissolving sodium alginate (SA, Adamas-beta) in deionized water under heated. A mixture of (A) and (B) was obtained by drop-wise addition of suspension (A) to the SA solution, and the mixtures were stirred constantly for 1 h to get a homogeneous mixture. Subsequently, the mixture was later injected into a glass bottle or a self-made mold and then carefully immersed in Fe^{3+} ions solution for 12 h to produce hydrogels. The formed hydrogel bodies were then washed with deionized water to remove non-coordinated Fe^{3+} ions.

In order to prepare hydrogels of different shapes, the mixture is placed in a mold of different shapes and stored in a refrigerated state for one night, and then the coagulated mold was placed in the Fe^{3+} solution for 12 h. The formed hydrogel bodies were then washed with deionized water to remove non-coordinated Fe^{3+} ions.

Detecting β-lactamase: Penicillin was dissolved in serum to 30 mg L^{-1} and adjusted pH to 4.5, and put the hyfrogel immersed into the prefabricated serum. After added various moments of β-lactamase and incubated for 20 min at 32 ℃, the hydrogel was measured PL spectra using a FLS920 spectrometer, the emission intensities of **1**@SA was recorded. The slop (S) was obtained from linear fitting between fluorescent intensity and concentrations of enzymes. The limit of detection (LOD) was calculated with the equation: LOD = $3S_b/S$ (where S_b is standard deviation of blank sample). All experiments were triplicated. The photographs of hydrogels were shot after treatment with β-lactamase under a 365 UV lamp irradiated.

Characterization and Instruments: The powder X-ray diffraction (PXRD) patterns were recorded with a Bruker D8 ADVANCE diffractometer using Cu Kα radiation with 40 mA and 40 kV. SEM was performed on a Hitachi S-4800 field emission scanning electron microscope operating at 3 kV. Energy dispersive analysis of X-rays (EDX) spectrum and EDX-mapping image were obtained by the FE-SEM operating at 15 kV. X-ray photoelectron (XPS) spectra were recorded under ultrahigh vacuum (<10−6 Pa) at a pass energy of 93.90 eV with an Axis Ultra DLD spectrometer (Kratos, Japan) by using an Mg Kα (1253.6 eV) anode. All binding energies were adjusted by using contaminant carbon (C 1s = 284.8 eV). Attenuated total reflection Fourier transform infrared (ATR−FTIR) spectra were recorded from 4000 to 400 cm−1 using a Nicolet IS10 infrared spectrophotometer with a smart DuraSamplIR Diamond ATR accessory. The excitation and emission spectra of the solid samples were obtained on an Edinburgh FLS920 spectrophotometer with a 450 W xenon lamp as an excitation source. Luminescence lifetime measurements were carried out on an Edinburgh FLS920 phosphorimeter using a microsecond lamp (100 mW).



Scheme S1 Schematic diagram of the "ON-OFF-OFF-ON" luminescent trigger pattern.

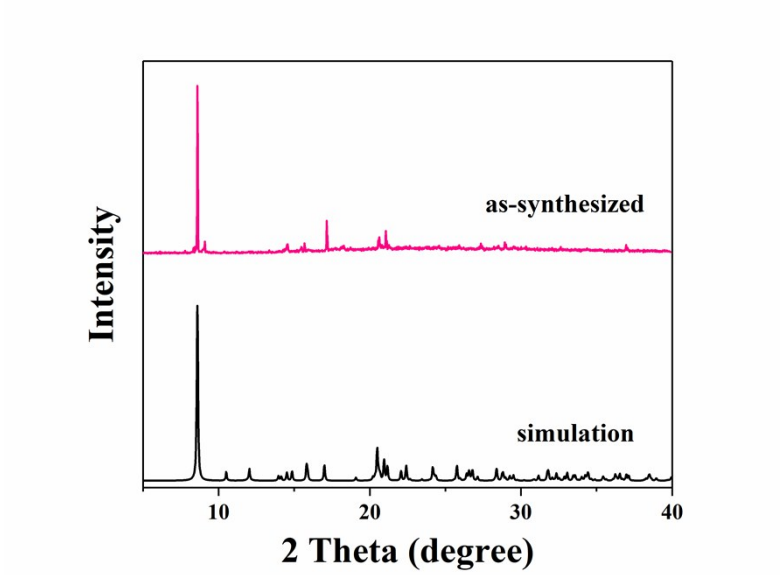


Fig. S1 PXRD patterns of simulated **1** and as-synthesized **1**.

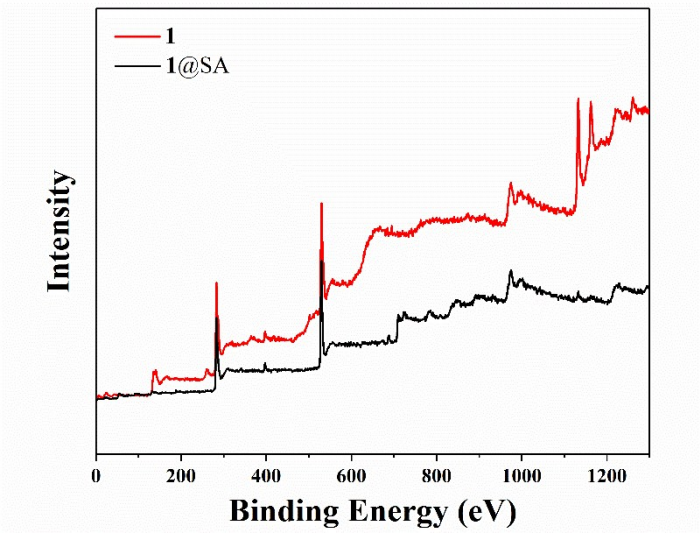


Fig. S2 XPS spectra of **1** and **1**@SA hydrogel.

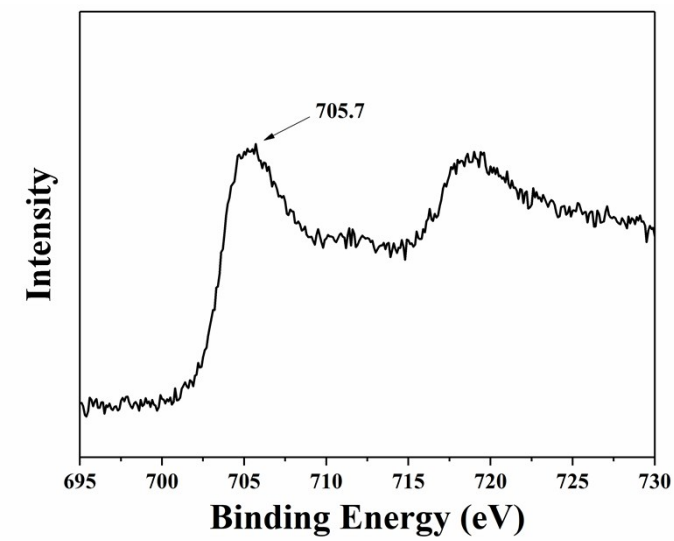


Fig. S3 Fe 2p XPS spectrum of **1**@SA.

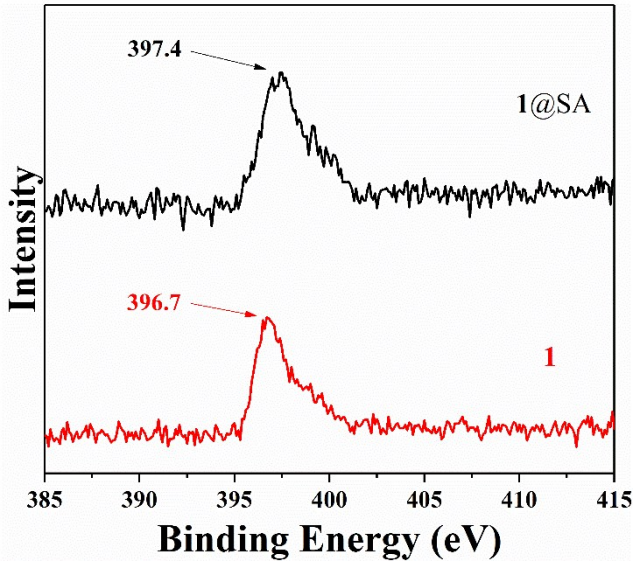


Fig. S4 N 1s XPS spectra of **1** and **1**@SA hydrogel.

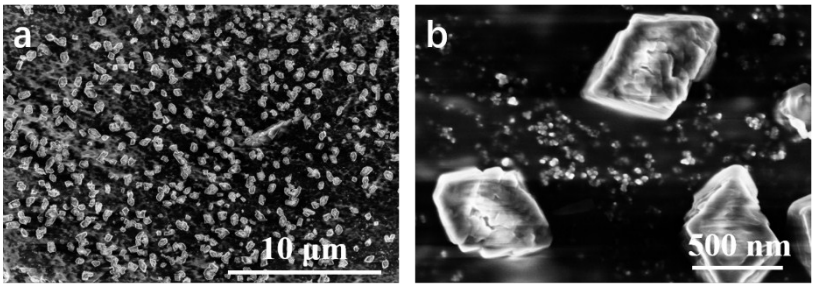


Fig. S5 SEM images of as-synthesized nanoscale **1** with irregular skew cube morphology.

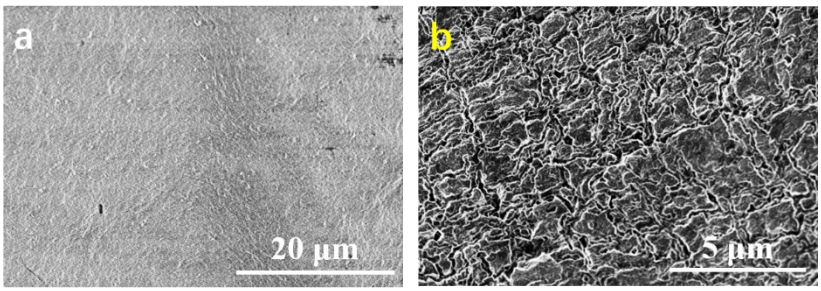


Fig. S6 SEM images of **1**@SA composite hydrogel at large (a) and amplification area (b).

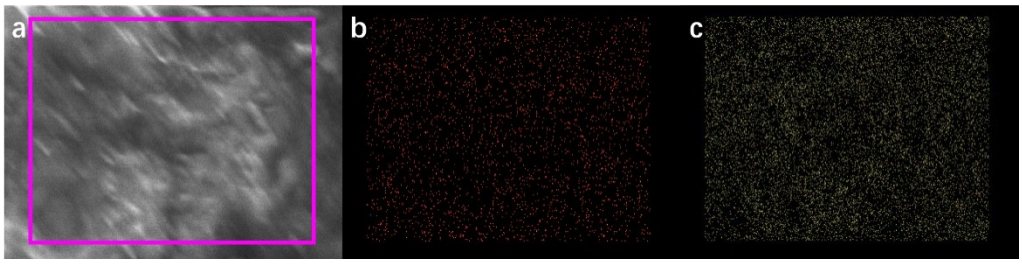


Fig. S7 EDX-mapping images of hydrogel 1@SA (a) for element Eu (b) and Fe (c).

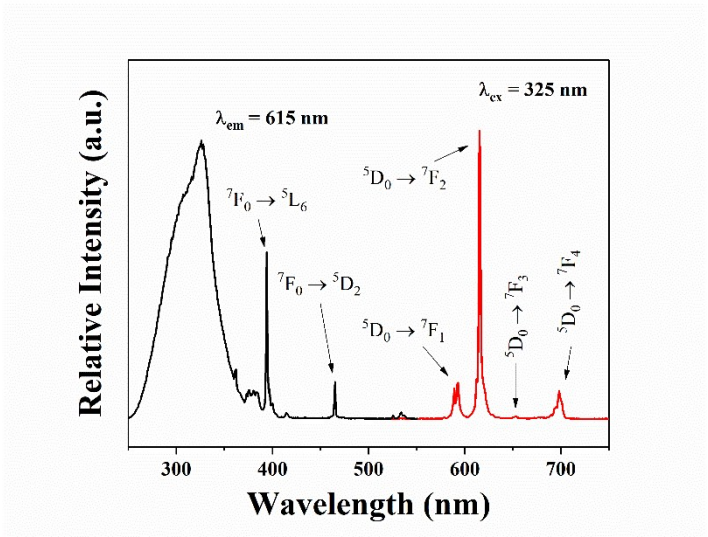


Fig. S8 Excitation and emission spectra of powder **1**.

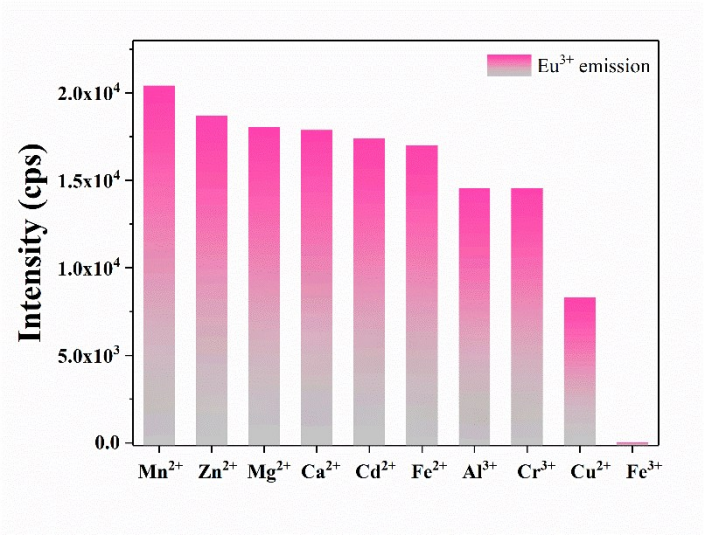


Fig. S9 Histogram for the Eu^{3+} emission of **1**@SA hydrogels undergoes various cation solutions immersion.

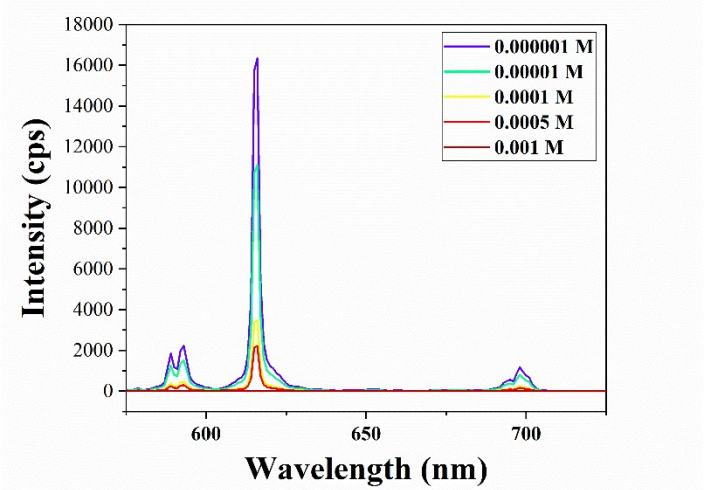


Fig. S10 Emission spectra of **1** undergo Fe^{3+} aqueous solutions with different concentration from 10^{-6} – 10^{-3} M.

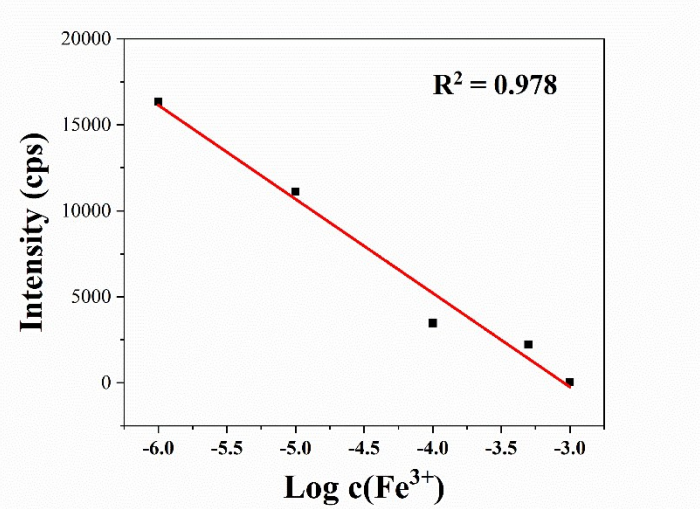


Fig. S11 Linear curve of the luminescent intensity of **1** toward Fe^{3+} concentration in aqueous solutions. The stern-volmer equation (R^2 = 0.978) is:

$$I_1 = -5460\log C_{Fe^{3+}} - 16621 \qquad (S1)$$

And the binding constant between Fe^{3+} and **1** is 5460.

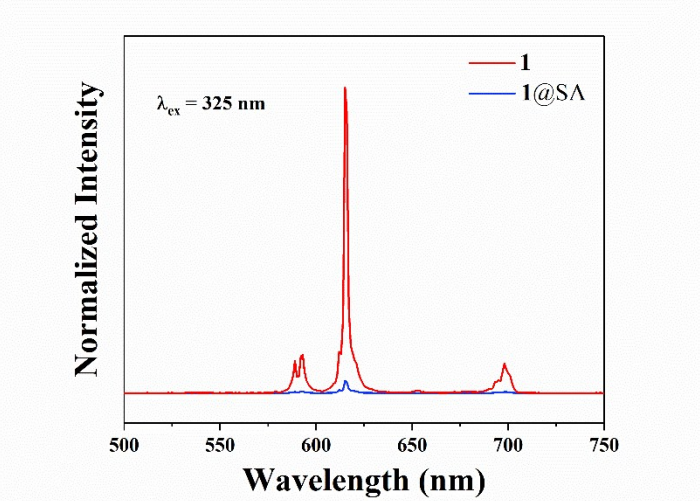


Fig. S12 A comparison of the emission intensities of **1** and **1**@SA. The emission intensities are normalized.

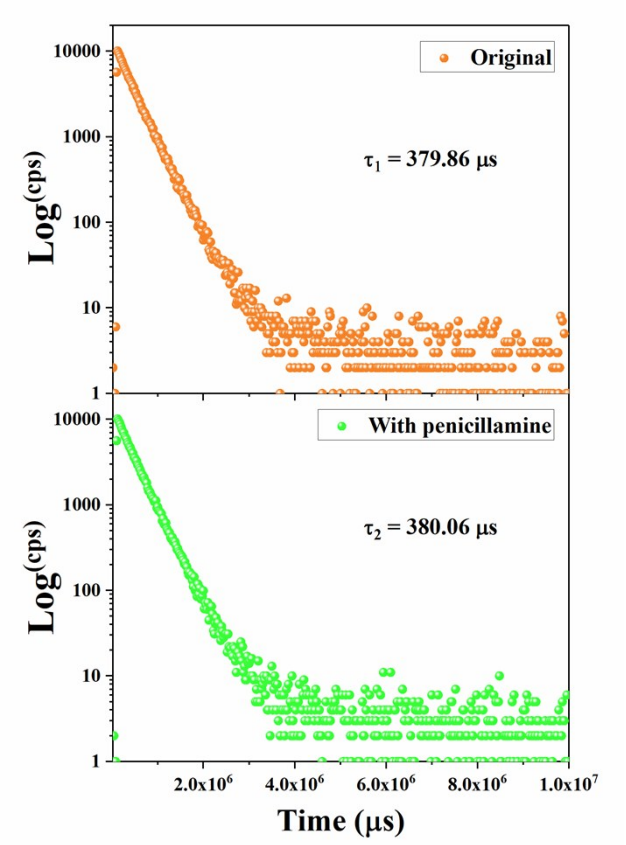


Fig. S13 Luminescence decay curves of **1**@SA hydrogels immersed in H_2O (top) and penicillamine solution (0.001 M) (down).

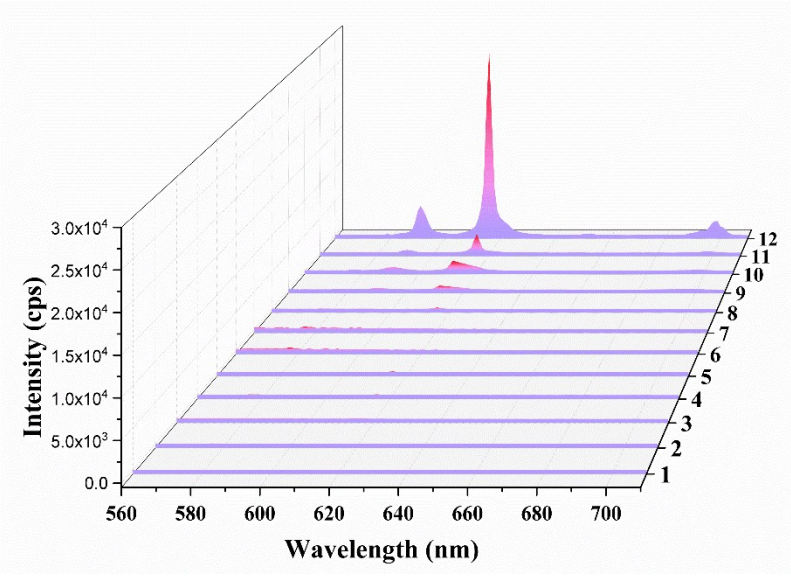


Fig. S14 Emission spectra of **1**@SA hydrogels immersed in various chemical solutions (1: Na^+, 2: K^+, 3: phenethylamine, 4: cysteine, 5: glutathione, 6: histamine, 7: histidine, 8: dopamine, 9: PO_4^{3-}, 10: glucose, 11: ascorbic acid, 12: penicillamine).

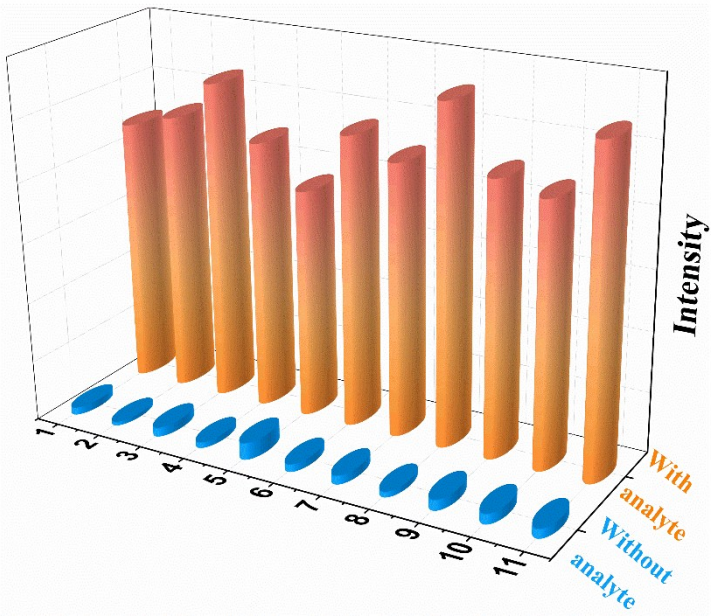


Fig. S15 Luminescence responses (blue: without penicillamine; orange: with penicillamine) of **1**@SA toward penicillamine in the presence of background of other chemicals (1: Na^+, 2: K^+, 3: phenethylamine, 4: cysteine, 5: glutathione, 6: histamine, 7: histidine, 8: dopamine, 9: PO_4^{3-}, 10: glucose, 11: ascorbic acid).

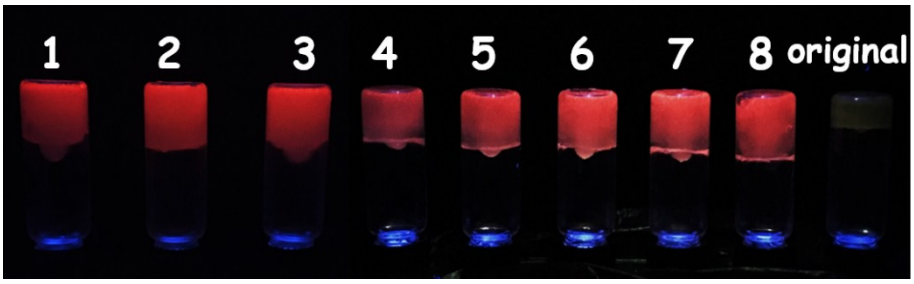


Fig. S16 Corresponding photographs of the luminescence responses of **1**@SA toward penicillamine in the presence of background of other chemicals (1: Na^+, 2: K^+, 3: phenethylamine, 4: histamine, 5: histidine, 6: dopamine, 7: glucose, 8: ascorbic acid).

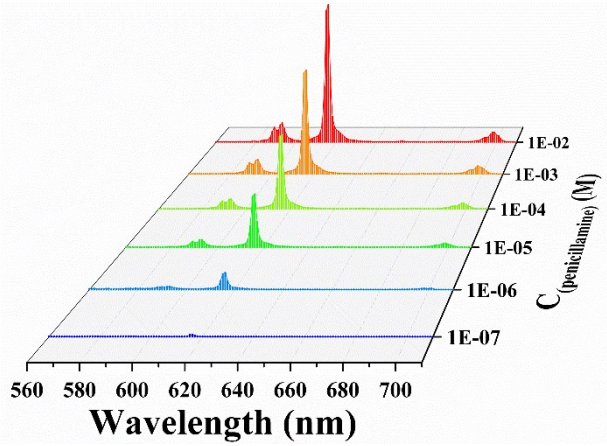


Fig. S17 The emission spectra of **1**@SA undergo penicillamine aqueous solutions with different concentration from 10^{-7} – 10^{-2} M.

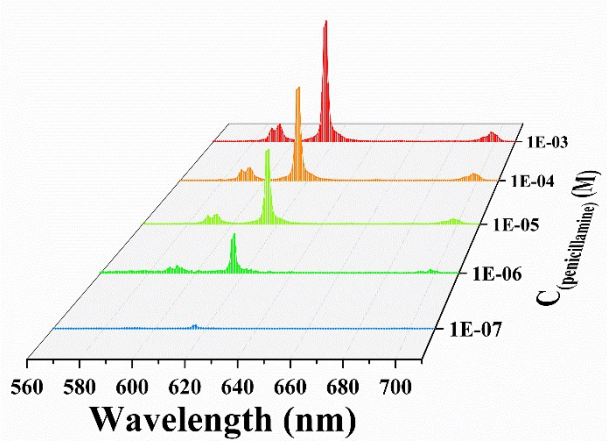


Fig. S18 The emission spectra of **1**@SA undergo different concentrations from 10^{-7} – 10^{-3} M of penicillamine in serum.

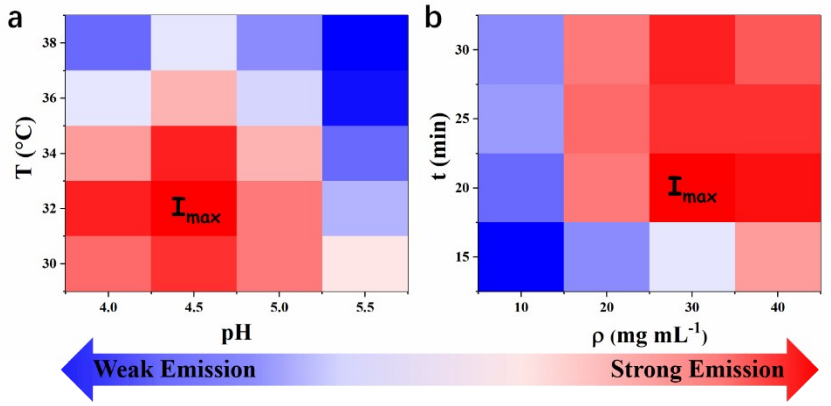


Fig. S19 Optimal selection of the conditions of β-lactamase activities test: (a) incubation temperature and pH; (b) reaction time and concentration of penicillin.

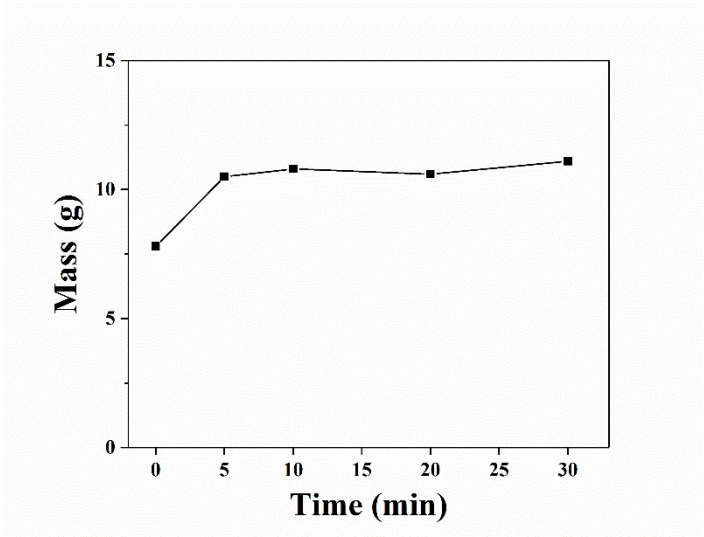


Fig. S20 The quality change of hydrogel 1@SA in water.

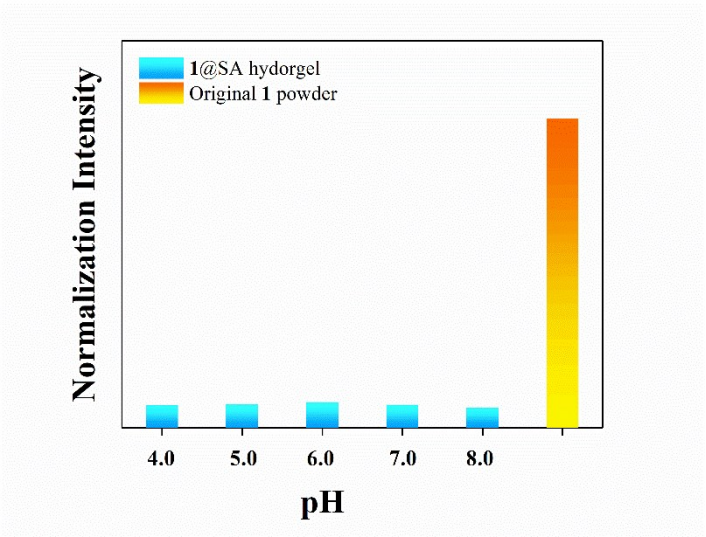


Fig. S21 Comparison of the emission intensities of **1**@SA immersed in different pH solutions for 20 min. The emission of original **1** powder was used as a reference for other samples, and the emission intensities are normalized.

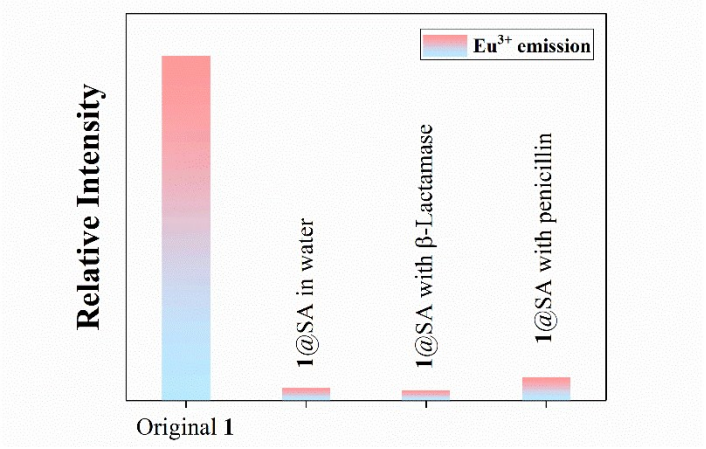


Fig. S22 The blank control experiment of **1**@SA, the emission of original **1** powder was used as a reference for other samples, and the emission intensities are normalized.

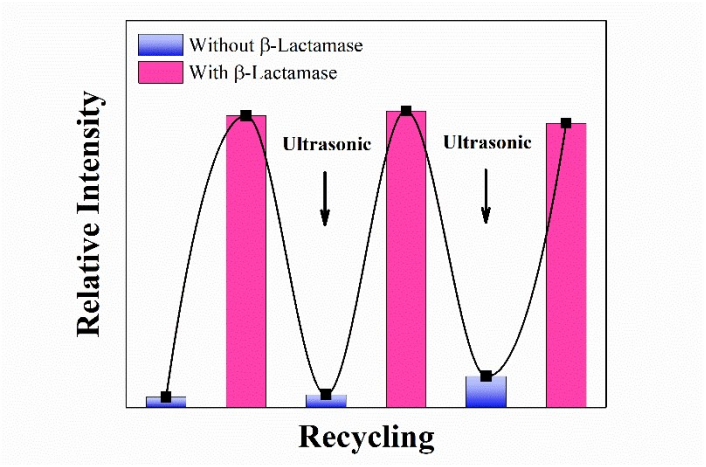


Fig. S23 The luminescence intensity of **1**@SA after five recycles.

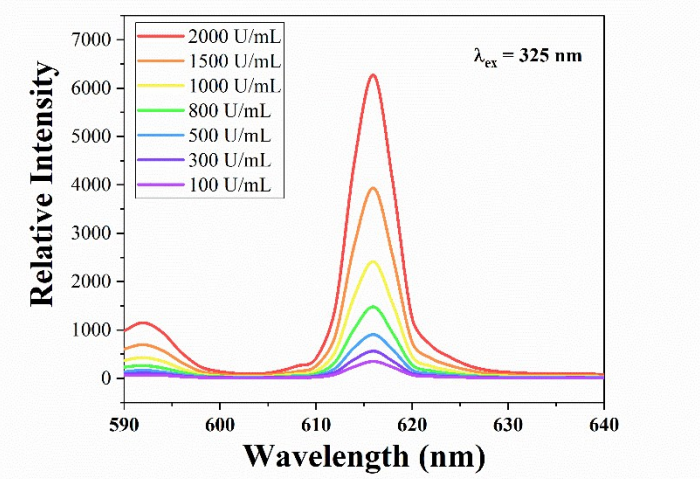


Fig. S24 Time-resolved emission spectra of 1@SA with different concentrations of β-lactamase.

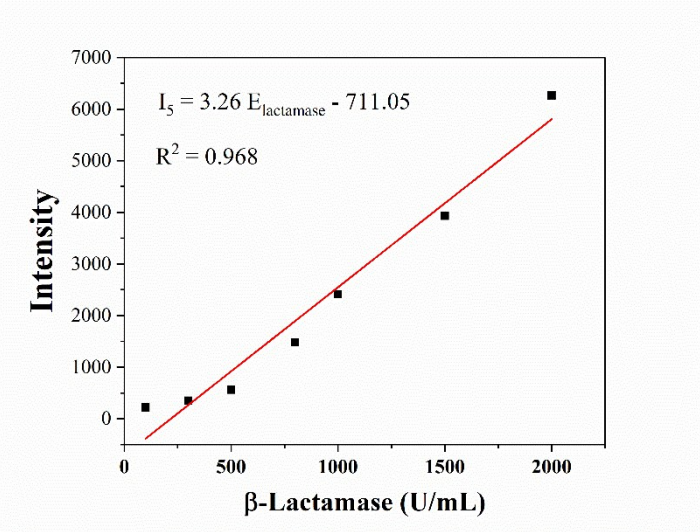


Fig. S25 Linear curve between intensities of **1**@SA from the time-resolved emission spectra and the β-lactamase concentrations.

Table S1 The comparison of the detecting performance of different sensing systems for the β-lactamase activities.

Sensor systems	Sample source	LOD	Reference
Iodometry kit	Milk	50 U mL^{-1}	39
Fluorescent sensor based on graphene oxide	Milk	0.5 U	40
HPLC	Milk	4 U mL^{-1}	41
Luminescent hydrogel	Serum	1.25 U mL^{-1}	This work

Reference

1. J. M. Zhou, W. Shi, N. Xu and P. Cheng, *Inorg. Chem.*, 2013, **52**, 8082.