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Electronic Supplementary Information

Cesium Lead Bromide as a colorimetric and fluorometric sensing platform for selective detection of Uric Acid

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CONTENTS

EXPERIMENTAL SECTION

Materials. Cesium Bromide (CsBr, 99.9%, Alfa Aesar), Lead Bromide ($PbBr_2$, 99.9 %, TCI), Dimethyl Sulfoxide (DMSO, 99%, Alfa Aesar), Toluene (99 % Alfa Aesar), Uric Acid (Sigma Aldrich), Urea (Sisco Research Laboratories), Glycine (Alfa Aesar), Ascorbic Acid (Alfa Aesar), Uracil (Alfa Aesar), Alanine (Sigma Aldrich), Glucose (Sigma Aldrich), Adenine (Alfa Aesar), Cystine (Alfa Aldrich), NaCl (Alfa Aldrich), KCl (Alfa Aldrich), Creatinine (Sigma Aldrich), Hippuric Acid (TCI) were commercially available. All chemicals were used without purification.

Instruments. The fluorescence emission spectra were recorded using a Hitachi F-2700 fluorescence spectrophotometer at room temperature. The decay of fluorescence spectra was measured using (Horiba Scientific, instrument) model. The surface morphologies of $CsPbBr_3$ metal halide perovskites (MHPs) were analyzed by using Gemini 500 FE-SEM instrument and energy dispersive compositional mappings were recorded by using SEM (JEOL-JSM-6390LV). The High-resolution Transmission electron microscope (HR-TEM) images were captured using (Model: JEM-2100, JEOL, USA). XRD was measured with Bruker D8 advanced eco P-XRD system. The FTIR spectra of the samples were performed using a Nicolet Impact-410 IR spectrometer (USA) in the KBr medium at room temperature in the range of 4000–400 cm^{-1}. A Shimadzu UV-2550 spectrophotometer was used to record the electronic absorption spectra of the samples in the wavelength range of 200-800 nm. The chemical compositions were analyzed by X-ray photoelectron spectroscopy (XPS, Perkin Elmer model 1257), instrument.

Preparation of perovskite $CsPbBr_3$. Perovskites are prepared through the traditional one-pot anti-solvent method at room temperature.[1-2] First 2.5 mmol of Cesium Bromide (CsBr) (0.5320 g) and 2 mmol of Lead (II) Bromide ($PbBr_2$) (0.734 g) were added to 15 mL DMSO. The solution was stirred for 12 h until the solid completely dissolved. Later the solution was quickly injected into 150 mL of toluene. The obtained product was centrifuged and washed with toluene and then placed in a vacuum oven at 80 °C.

Measurement of Fluorescence lifetime. The relative PLQY of the passivated perovskites were measured while taking Rhodamine B as a reference (Quantum Yield = 97 % in ethanol) with the equations as follows.[3-4]

$$\Phi_{fx} = \frac{\eta_x^2}{\eta_{Rhodamine\ Blue}^2} . \frac{A_{Rhodamine\ Blue}}{A_x} . \frac{F_x}{F_{Rhodamine\ Blue}} . \Phi_{fRhodamine\ Blue}$$

Where η is the refractivity (η = 1.36 for ethanol and η= 1.49 for toluene), A is the absorbance which is basically lower than 0.01 to avoid internal filter effects and F is the integral absorption area in the luminescence spectra.[4]

Methods for stability experiments:

0.1 mmol of $CsPbBr_3$ (0.057 g) was dispersed in 10 mL toluene and sonicated for 30 mins to get a homogeneous mixture. 3 mL of perovskite solution was aliquot in a cuvette and their respective luminescence peak was recorded under the excitation wavelength of 380 nm with the different interval of time under 80% humid condition. The photostability test was performed while dispersing 0.057 g of perovskite in a 10 mL toluene. Then 3 mL from the above solution was taken as a stock solution. The solution was further illuminated under the wavelength of 365 nm UV-lamp for a period of 8 hours. Their changes in PL intensity were measured under the excitation wavelength of 380 nm.

Fluorescence Assay of Uric-Acid using $CsPbBr_3$-based sensor. To carry out the fluorescence titration experiment a suspension of $CsPbBr_3$ perovskite in toluene having a concentration of (0.57 g/100 mL) was prepared and sonicated for 30 mins to get a homogeneous suspension. 3 mL of this suspension was placed in a quartz cuvette and to that 50 µL volume of UA solution with known concentration is added. The fluorescence spectra were measured with an excitation wavelength of 380 nm.

Detection of Uric Acid in real samples. The serum samples were collected as left-out blood serum samples from Pathology section of the Health Centre of Tezpur University (Napaam, Tezpur) with due consent from the hospital authority. The samples were diluted 100 times. Then the samples were mixed with different concentrations of UA for fluorescence measurements. The fluorescence spectra of as measured samples were monitored and then the recovery rate of the blood samples was calculated under the excitation wavelength of 380 nm.

The paper-based sensor of the perovskite $CsPbBr_3$ for UA sensing. To investigate the visual detection of Uric Acid by $CsPbBr_3$, a paper sensor was fabricated where 1 mL of dispersed perovskite solutions were first added to 1cm×1cm cellulose paper respectively. After then a

few drops of UA with varying concentrations were dripped into the following paper. The fluorescence colour response was observed under the UV emitting lamp of 365 nm wavelength.

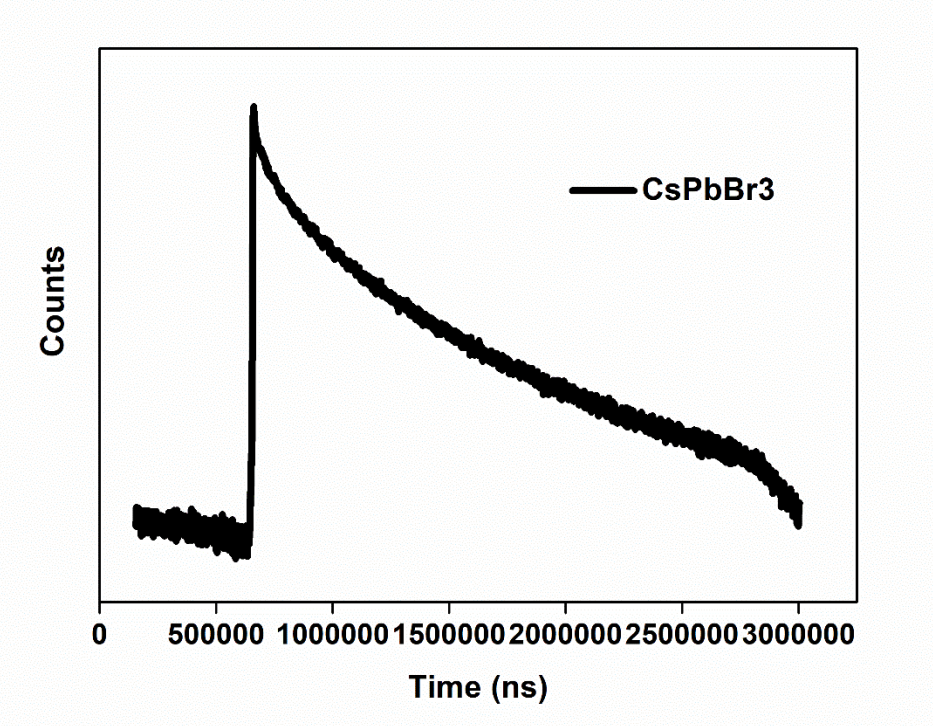

Figure S1. Time-resolved Photo-luminescence decay graph of $CsPbBr_3$.

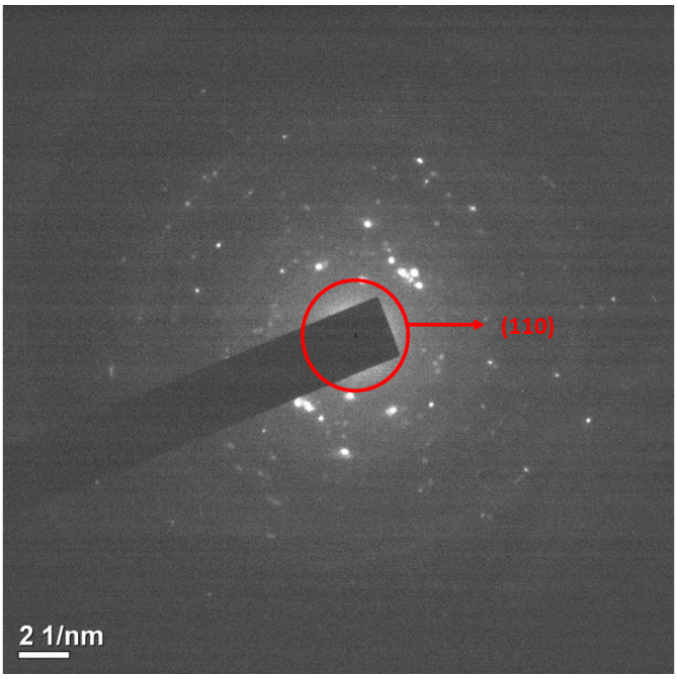

Figure S2. Selected area diffraction (SAED) pattern of $CsPbBr_3$.

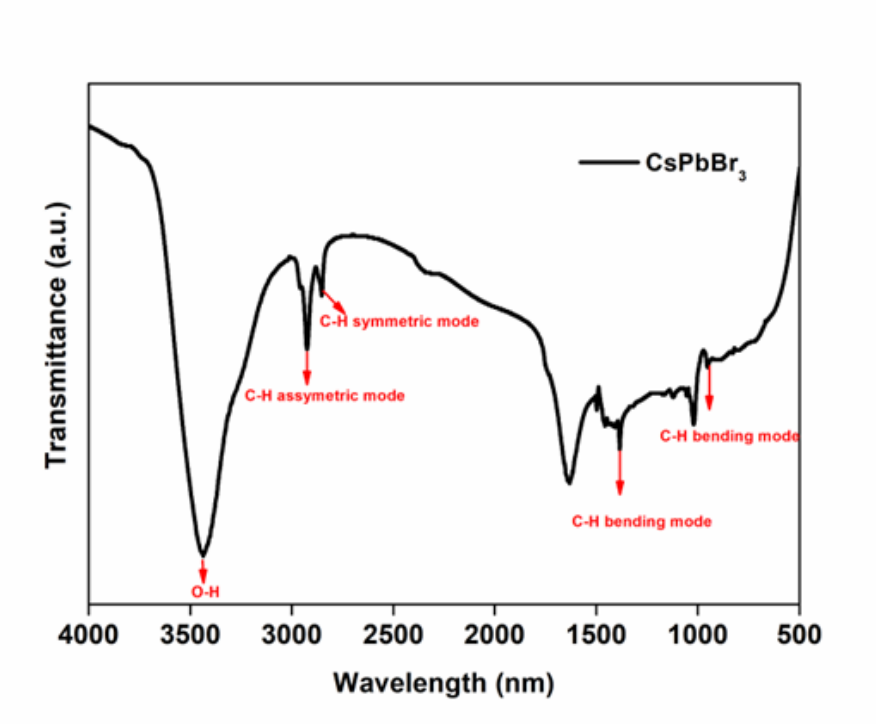

Figure S3. FT-IR spectra of $CsPbBr_3$.

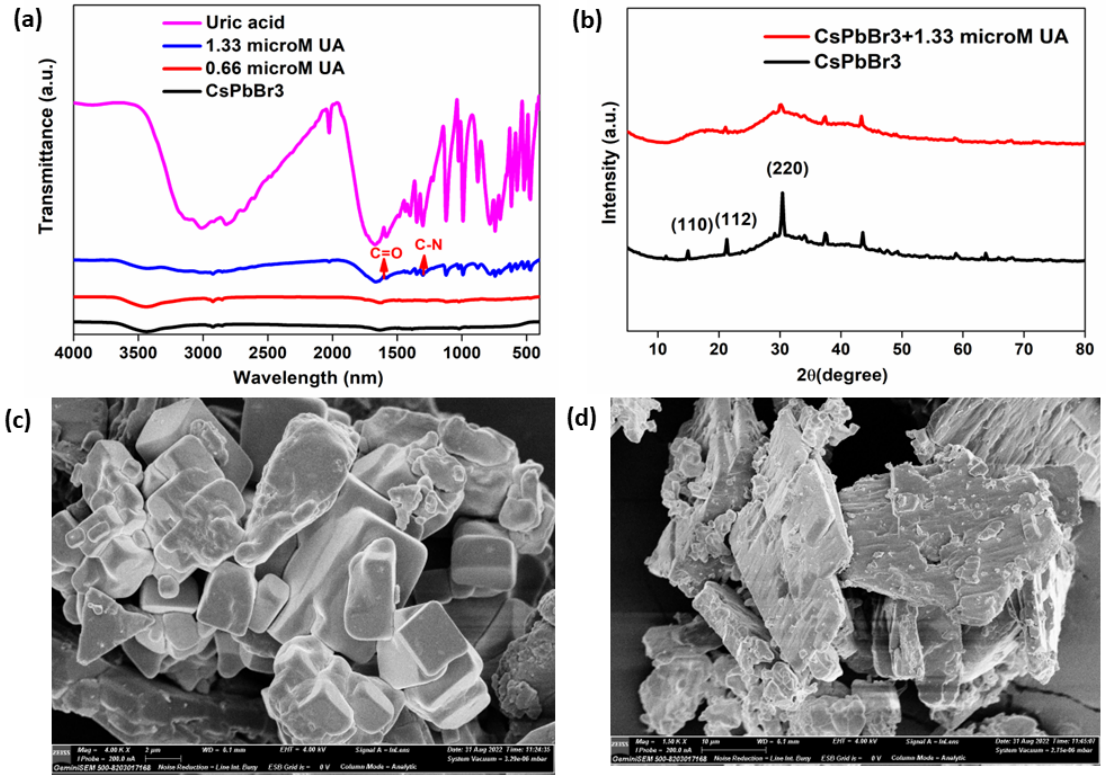

Figure S4. (a) FT-IR spectra of $CsPbBr_3$ titrated with various concentrations of UA (b) P-XRD spectra of $CsPbBr_3$ after exposure to 1.33 microM UA. (c) FE-SEM image of $CsPbBr_3$(d) FE-SEM image of structural degradation after adding UA to $CsPbBr_3$.

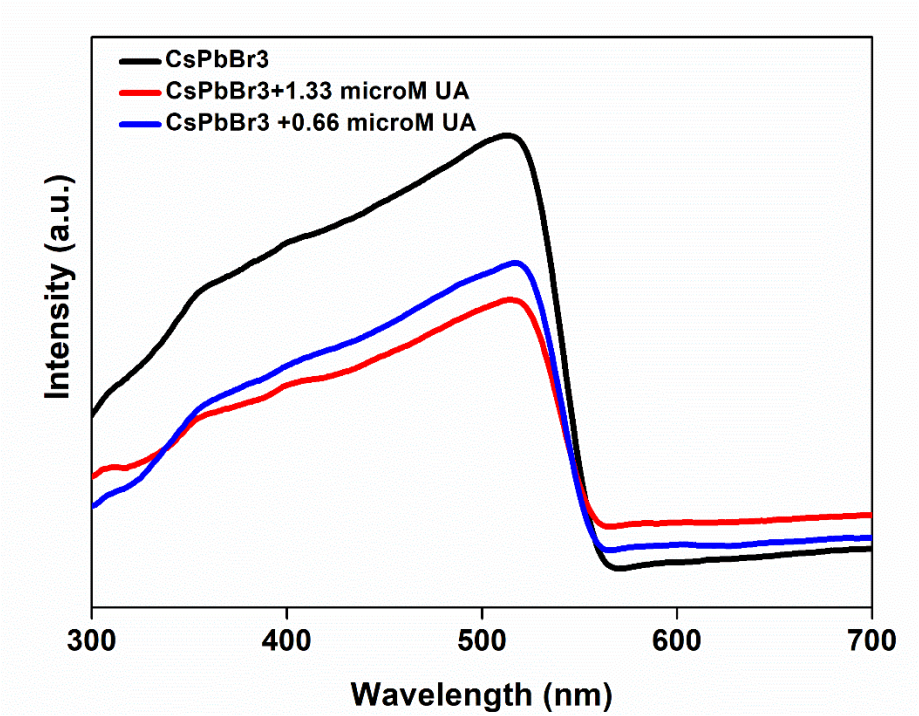

Figure S5. Solid-state UV-Vis absorption of $CsPbBr_3$ titrated with various concentrations of UA.

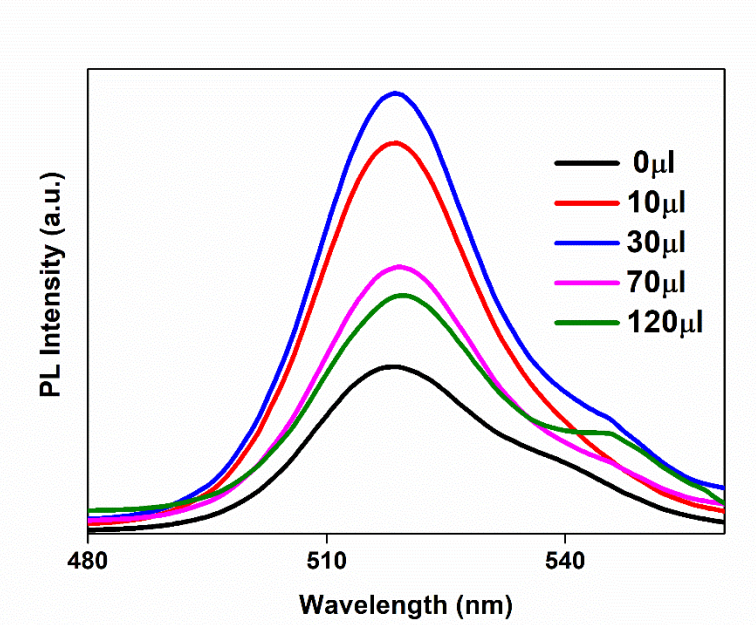

Figure S6. The PL intensity of $CsPbBr_3$ with the addition of different volumes of water.

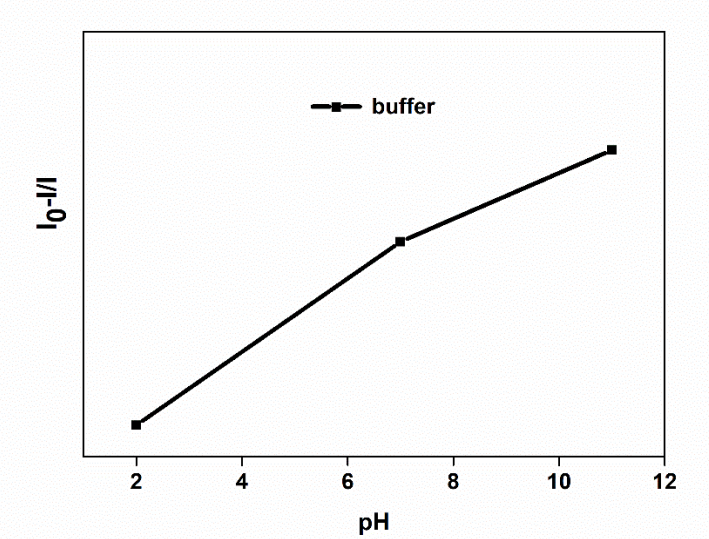

Figure S7. Effect of different buffer solutions (acidic: HCl + KCl, pH=2 neutral: phosphate, pH=7 and basic: $NaHCO_3$ and Na_2CO_3 pH=10.6) on the sensing performance of $CsPbBr_3$.

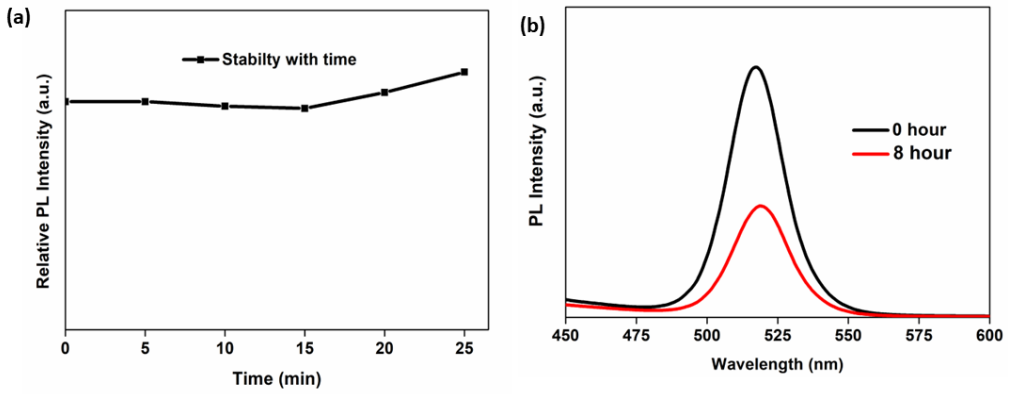

Figure S8. (a) Stability of $CsPbBr_3$ dispersion with respect to time under humid condition 80% and (b) Photostability of $CsPbBr_3$ dispersion under the illumination of 365nm wavelength UV-lamp.

Table S1. Summary of optical properties of $CsPbBr_3$

	FWHM	**PLQY (%)**	**λmax (absorption)**	**λmax (luminescence)**	**Band gap**
$CsPbBr_3$	20 nm	60	530 nm	520 nm	2.6 eV

Table S2. Concentration-dependent lifetime values

System	τ 1(ns)	τ 2 (ns)	τ av (ns)
CsPbBr3	21.19	10.95	8.76
CsPbBr3+0.66µM	10.8	21.7	8.64
CsPbBr3+1.33µM	1.01	20.3	8.15

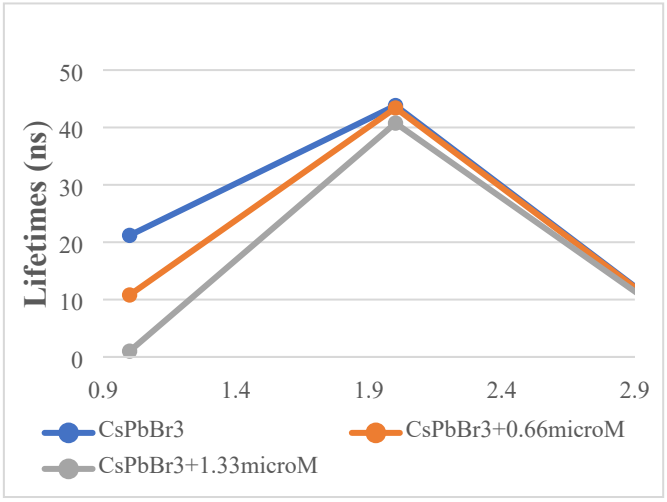

Figure S9. Line chart of the respective lifetimes of systems.

Table S3. A Comparative study of a few fluorescence sensor probe systems for detection of UA

Sensor probe	LOD(µM)	ref
$CsPbBr_3$	0.373	This work
Cu^{2+} @ MIL-91 (Al: Eu)	1.6	5
N-MWCNTs/ PtNPs	2.1	6
Xerogel	<10	7
AuNCs	6.6	8
Uricase/HRP-CdS QDs	125	9
$NaYF_4$:Yb^{3+}, Tm^{3+}	6.7	10

CuInS/ZnS	0.05	11
CS-AuNC/PVP-AuNP	1.7	12
Hf-UiO-66-Py MOF	1.4	13
Pyrene-based amphiphilic receptor	0.0031	14
CdTe (Quantum dots) coated with 2- Mercaptoethylamine	0.103	15
Carbon dot from pork	0.05	16
Carbon dot entrapped in Cr-MOF	1.3	17
Eu-MOF	0.689	18
UiO-PSM	0.0023	19
COOH-nanoflakes	1	20
CdTe capped with (glutathione,3-marcaptopropionic acid and thioglecerol)	0.1	21
Luminol - terbium	0.028	22
Carbon -dot with MnO_2	0.045	23
Carbon-dot with MONT	4.3	24
3- mercaptopropionic acid capped ZnS: Zn-CuS	0.044	25

Table S4. Sensing applications of perovskite nanostructure

Perovskite sensing probe	**Detection method**	**Analyte**	**Ref.**
Cs_4PbBr_6@$CsPbBr_3$	Electro chemiluminescent	Bisphenol A	26
Cs_4PbBr_6@$CsPbBr_3$	Fluorescence	2,4 dinitrophenyl hydrazine	27
$CsPbBr_3$	Electrochemical	Human respiration monitoring	28
ZnO/ $CsPbBr_3$	Electrochemical	NO_2	29

$CsPbBr_3$	Fluorescence	Water content in herbal medicine	30
MIP@$CsPbBr_3$	Fluorescence	Omethoate	31
Tributylene oxide-$CsPbBr_3$	Electrochemical	H_2S	32
NH_2 functionalized $CsPbBr_3$	Fluorescence	Iodide ion	33
Molecularly imprinted mesoporous silica - CsPbBr3	Fluorescence	2,2 dichlorovinyldimethyl phosphate	34
Al_2O_3,$BaTiO_3$/TiO_2@Cs4PbBr6/$CsPbBr_3$	Electrochemical	Humidity	35
Ag^+@UiO-66-NH_2 decorated $CsPbBr_3$	Electrochemical	Nitrofurazone	36
MIP@CsPbBr3	Fluorescence	Phoxim	37
Cu/$CsPbBr_3$	Fluorescence	Glucose	38
EMT zeolite/$CsPbBr_3$	Fluorescence	Humidity	39
Cellulose/ $CsPbBr_3$	Colorimetric	Cl^-/I^-	40
Eu@BTC/ $CsPbBr_3$	Fluorescence	Hg^{2+}	41
$CsPbBr_3$	Fluorescence	Hg^{2+}	42
$Ti_3C_2T_x$-MXene-$CsPbBr_3$	Fluorescence	Cd^{2+}	43
SiO_2@$CsPbBr_3$	Fluorescence	Cl^-	44
$CsPbBr_3$	Fluorescence	Cu^{2+}	45
m-PEG@SiO_2/$CsPbBr_3$	Fluorescence	Glutathione/Hg^{2+}	46
$CsPbBr_3$	Fluorescence	Cl^- in sweat	47
CQD@CTAB/$CsPbBr_3$	Fluorescence	Fe^{3+}	48
Eu^{3+}/$CsPbBr_3$	Fluorescence	Temperature	49
ZnO/ $CsPbBr_3$	Electrochemical	NO_2	50
COOH/$CsPbBr_3$	Fluorescence	Mycobacterium Tuberculosis	51

APTES/ Cs_4PbBr_6@$CsPbBr_3$	Fluorescence	Fe^{3+}	52
APTES/$CsPbBr_3$	Fluorescence	Tetracycline	53
$CsPbBr_3$	Fluorescence/Colorimetric	Benzoyl Peroxide	54
$CsPbBr_3$	Fluorescence	Chloride/Arsenite	55
SiO2@gold/CsPbBr3	Fluorescence	Cu^{2+}	56

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