Electronic Supplementary Information

Stimulus-Triggered Luminescent Hydrogel with Al³⁺ for Visible Color

Tunability in Advanced Information Encryption Applications

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Table S1 Feed formula of the hydrogels.

Hydrogel	PVA	NMA	Воро	DPA	LEuH NSs	LTbH NSs	DMSO	Water	APS	TEMED
	g	g	mg	mg	μL	μL	μL	mL	mg	μL
NPG	0.1	1.1	0	3.2	0	200	0	1.3	3	5
NPB'R	0.1	1.1	4	3.2	200	0	100	1.2	3	5
NPB'G	0.1	1.1	4	3.2	0	200	100	1.2	3	5
NPB'GR	0.1	1.1	4	3.2	100	100	100	1.2	3	5



Figure S1 XRD of LEuH and LTbH.



Figure S2 FTIR spectra of LEuH and LTbH.



Figure S3 TGA curve of the LEuH and LTbH under N_2 atmosphere.



Figure S4 SEM images of a) LEuH and b) LTbH.



Figure S5 DLS plot of the LEuH NSs (Gly) and LTbH NSs (Gly) dispersion.



Figure S6 AFM images of a) LEuH NSs and c) LTbH NSs. The corresponding height curves of b) LEuH NSs and d)

LTbH NSs.



Figure S7 The synthetic route of Bopo.



Figure S8 ¹H NMR spectrum of Bopo.



Figure S9 ¹³C NMR spectrum of Bopo.



Figure S10 FTIR spectra of Bopo and Bopo-Al³⁺.



Figure S11 XRD patterns of NPB, NPG and NPR.



Figure S12 Rheological behavior of NPB, NPG and NPR.



Figure S13 The self-healing hydrogel NPB-G-R under stretching and UV (λ_{ex} = 254, 365 nm).



Figure S14 Tensile stress-strain curve of blank hydrogel.



Figure S15 a) Cyclic loading–unloading curves of NPB at a tensile strain of 50% and b) at a compressive strain of 80%.



Figure S16 Digital photographs of NPB, NPG, NPR and corresponding optical transmittances.



Figure S17 Characterization of NPB, NPG, NPR hydrogels. a-c) SEM picture of NPB, NPG, NPR hydrogels. d-f) EDS

mapping images of NPB, NPG, NPR hydrogels.



Figure S18 a) Emission spectra of NPB' immersed in various metal ion solutions including Na⁺ , K⁺ , Ca²⁺, Co²⁺, Ni²⁺, Cu²⁺, Zn²⁺, Fe³⁺ , Al³⁺, La³⁺, and Ce³⁺ (0.01 M) for 1min (λ_{ex} = 330 nm). b) Emission spectra of NPB to Al³⁺ in the presence of competitive metal ions including Na⁺ , K⁺ , Ca²⁺, Co²⁺, Ni²⁺, Cu²⁺, Zn²⁺, Fe³⁺ , Al³⁺, La³⁺, and Ce³⁺ (0.01 M) for 1min (λ_{ex} = 330 nm). c) Emission spectra of NPB in the presence of Al³⁺ at different concentrations (10⁻⁹-10⁻¹ M) (λ_{ex} = 330 nm). d) Linear relationship between luminous intensity and Al³⁺ concentration.



Figure S19 Al 2p spectrum of NPB.



Figure S20 Changes of fluorescence emission spectrum of NPB treated with Al³⁺ solution.



Figure S21 a) UV-vis absorption spectra of blank hydrogel. b) Emission spectrum of blank hydrogel (λ_{ex} = 330 nm).



Figure S22 Fluorescent excitation spectra of hydrogels NPB, NPG and NPR hydrogels.



Figure S23 Temperature-dependent emission spectra of a) NPB, b) NPG, and c) NPR from -55° C to 75° C (λ_{ex} = 330



nm, 280 nm and 280 nm).

Figure S24 Emission spectra of a) NPB, b) NPG and c) NPR immersed in water at 0 to 120h (λ_{ex} = 330 nm, 280 nm

and 280 nm).



Figure S25 Emission peak life attenuation curve of a) NPB b) NPG, NPR at 410 nm, 545 nm and 616 nm, respectively (λ_{ex} = 330 nm, 280 nm and 280 nm).



Figure S26 CIE (1931) color coordinates of hydrogels with increasing Al³⁺ concentration (λ_{ex} = 290 nm).