Supplementary Information (SI) for Analytical Methods.
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Supporting Information

Responsive red carbon dots with dual-wavelength emission for anti-counterfeiting

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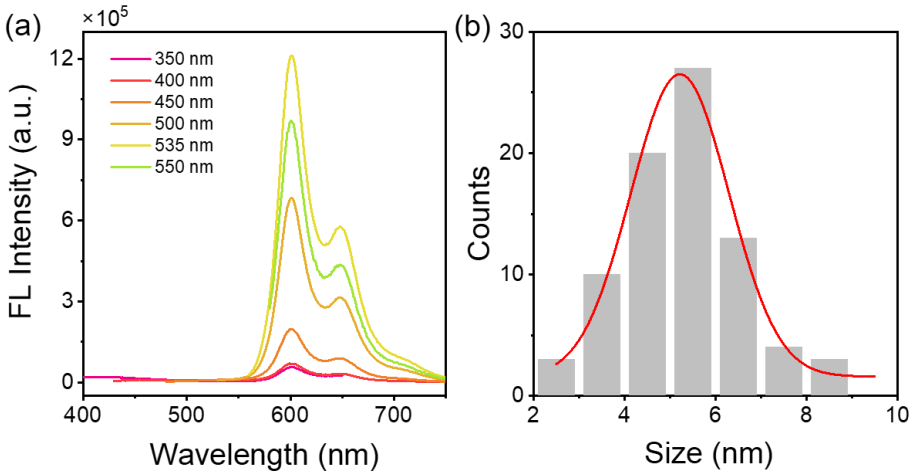

Fig. S1 (a) Fluorescence emission spectra of R-CDs at different excitation wavelengths. (b) Particle size distribution diagrams of R-CDs

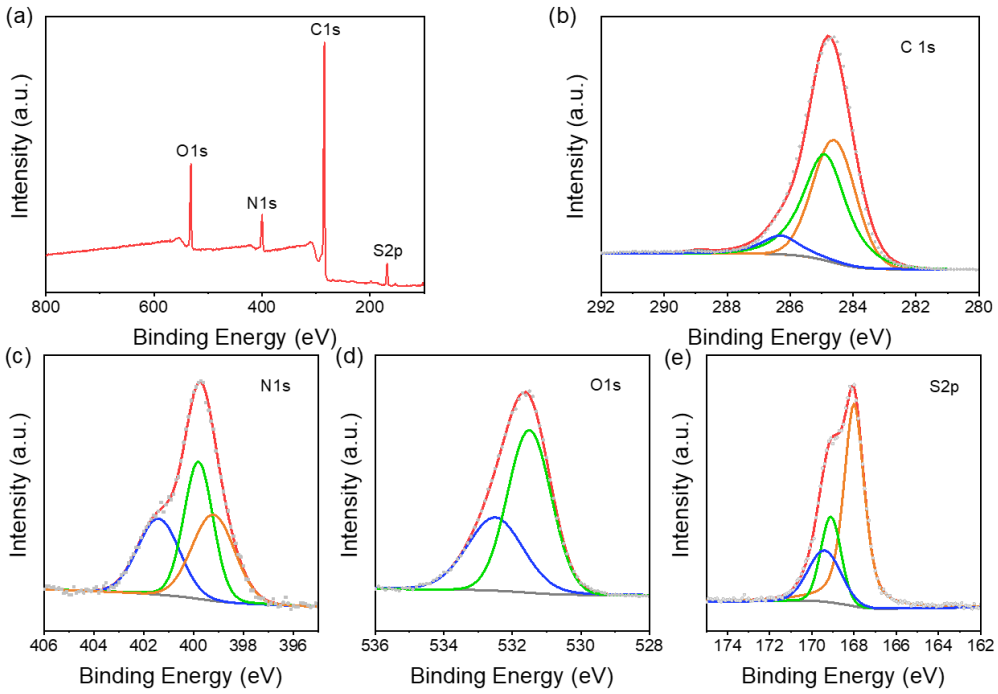

Fig. S2 (a) XPS survey spectra, high-resolution (b) C 1s XPS spectra, (c) N 1s XPS spectra, (d) O 1s XPS spectra and (e) S 2s XPS spectra of R-CDs.

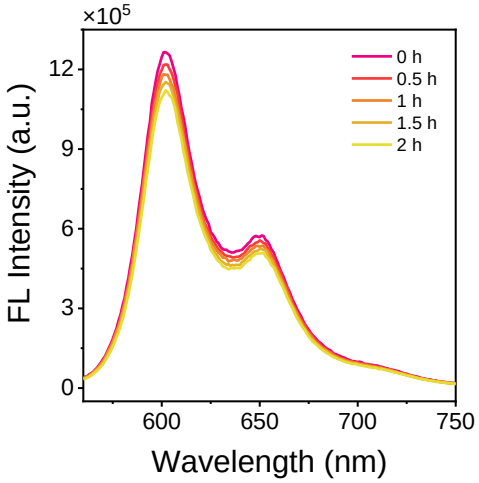

Fig. S3 Stability of R-CDs under UV irradiation.

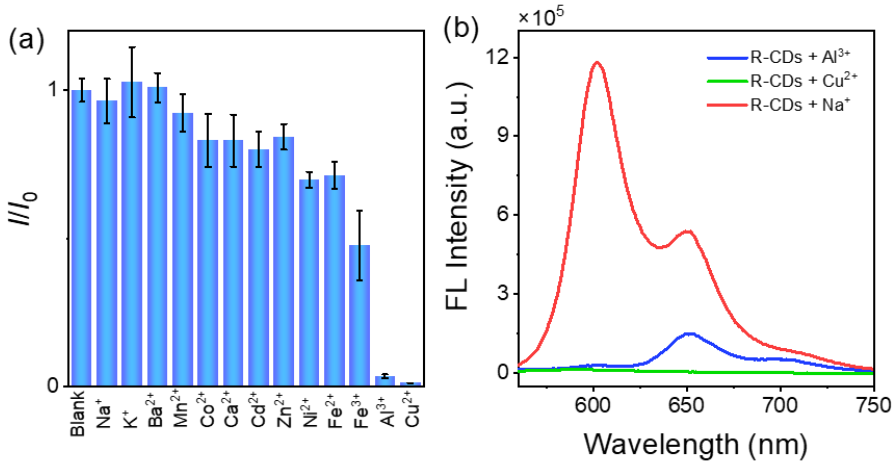

Fig. S4 FL intensity of R-CDs at 601 nm stimulated by various metal ions.

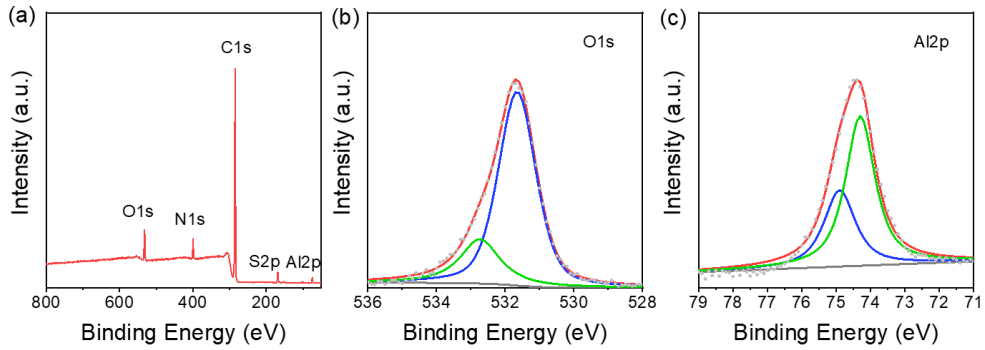

Fig. S5 (a) XPS survey spectra, high-resolution (b) O 1s XPS spectra, (c) Al 2p XPS spectra spectra of Al^{3+}-R-CDs.

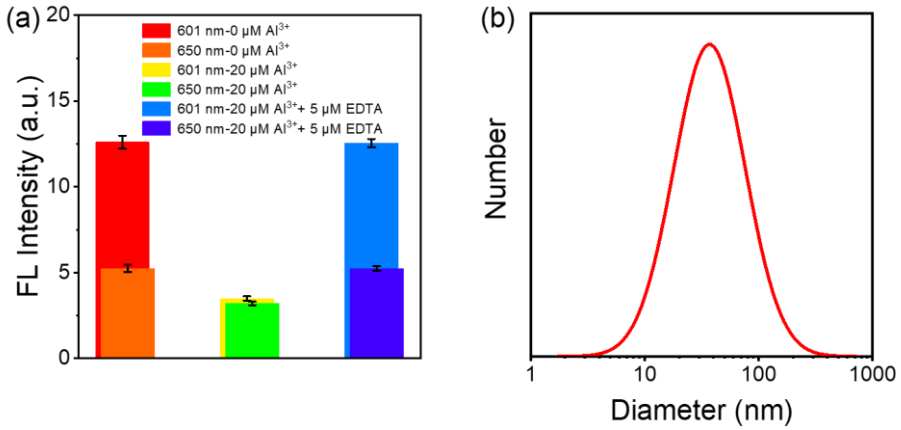

Fig. S6 (a) Changes in peak intensity in 0 μM Al^{3+}, 20 μM Al^{3+}, and 20 μM Al^{3+}+ 5 μM EDTA. (b) Size distribution of Al^{3+}-R-CDs from DLS.

As shown in Fig. S6a, the addition of ethylenediaminetetraacetic acid (EDTA) can effectively inhibit the quenching effect of Al^{3+} on R-CDs, which indicates the quenching behavior is barely affected by common chelating interference. Meanwhile, the DLS tests (Fig. S6b) revealed that the diameter of Al^{3+}-R-CDs in an ethanol solution was approximately 36 nm, indicate that Al^{3+} introduction only induces slight and negligible variation in particle size and aggregation state of the materials, excluding prominent aggregation-derived quenching effects. Considering that the addition of Al^{3+} alters the solution's pH and polarity in a manner analogous to direct acid introduction. As shown in Fig. S7b, in contrast to the fluorescence alterations induced by Al^{3+}, variations in pH and solvent can lead to shifts in the position of the fluorescence peak. Combined with consistent spectral characterization results, the coordination interaction between Al^{3+} and carboxyl/carbonyl groups is still the dominant mechanism for the selective fluorescence quenching.

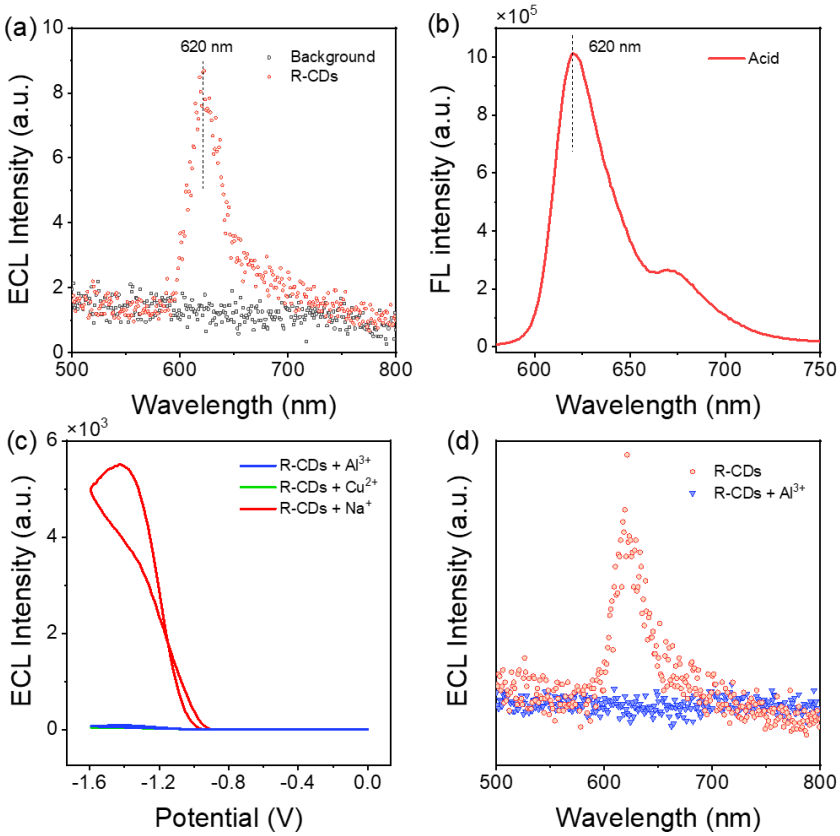

Fig. S7 (a) ECL spectrum and (b) FL spectrum of R-CDs in Ethanol/PBS and acid solution, respectively. (c) ECL response curves of R-CDs to Na^{+}, Cu^{2+} and Al^{3+}. (d) ECL spectrum of R-CDs with and without of Al^{3+}.

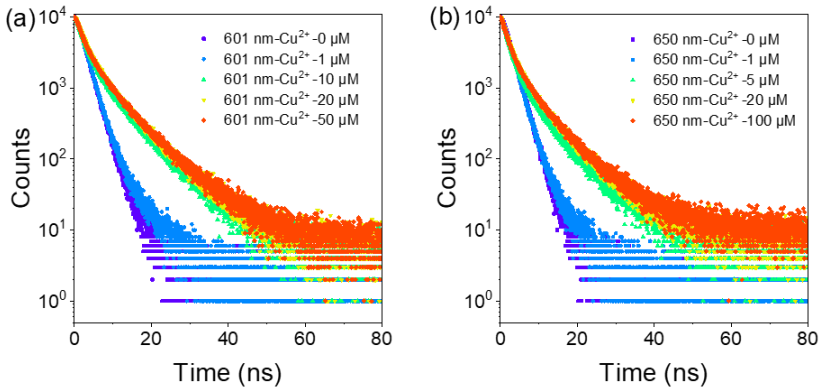

Fig. S8 Time-resolved photoluminescence decay of R-CDs with with Cu^{2+} at (a) 601 nm and (b) 650 nm.

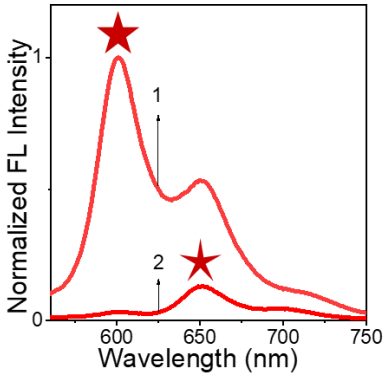

Fig. S9 After immersing the above tags in solutions, the solutions observed with fluorescence spectrometer.

Table 1 Time resolved decay parameters for R-CDs with different concentrations of ions. (λ_{ex} = 460 nm)

	$\tau_{average}$ / ns	τ_1 / ns	τ_2 / ns	τ_3 / ns
601-Cu-0	1.445	1.994	4.069	0.713
601-Cu-1	1.468	2.051	5.773	0.688
601-Cu-10	2.058	2.154	0.355	7.515
601-Cu-20	2.235	2.320	0.416	7.731
601-Cu-50	2.171	2.203	0.439	7.818
650-Cu-0	1.431	1.933	3.217	0.724
650-Cu-1	1.430	1.982	4.553	0.692
650-Cu-10	1.605	1.795	0.341	6.969
650-Cu-20	1.848	1.973	0.365	7.274
650-Cu-50	1.805	1.880	0.398	7.296
601-Al-0	1.445	1.994	4.069	0.713
601-Al-1	1.457	2.015	5.628	0.706
601-Al-10	1.709	2.131	0.557	7.383
601-Al-20	1.877	2.016	0.513	7.235
601-Al-50	1.784	1.905	0.525	7.027
650-Al-0	1.431	1.933	3.217	0.724
650-Al-1	1.233	1.613	3.594	0.654
650-Al-10	0.937	1.111	5.110	0.718
650-Al-20	0.906	1.013	5.426	0.773
650-Al-50	0.886	0.951	5.383	0.808

The fluorescence decay curves are fitted with tri-exponential functions, indicating the coexistence of multiple emissive centers in R-CDs. The three lifetime components τ_1, τ_2, and τ_3 can be correspondingly attributed to intrinsic core states, low-energy surface defect states, and emissive sites related to surface functional groups, which are closely related to the generation of the main fluorescence peak.