Electronic Supplementary Material (ESI) for RSC Advances.

An invisible privacy 2D barcodes design and implementation with tunable fluorescent nanoparticles

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The excitation and emission spectra of Anthracene and Coumarin 6 are presenting in Fig.S1.

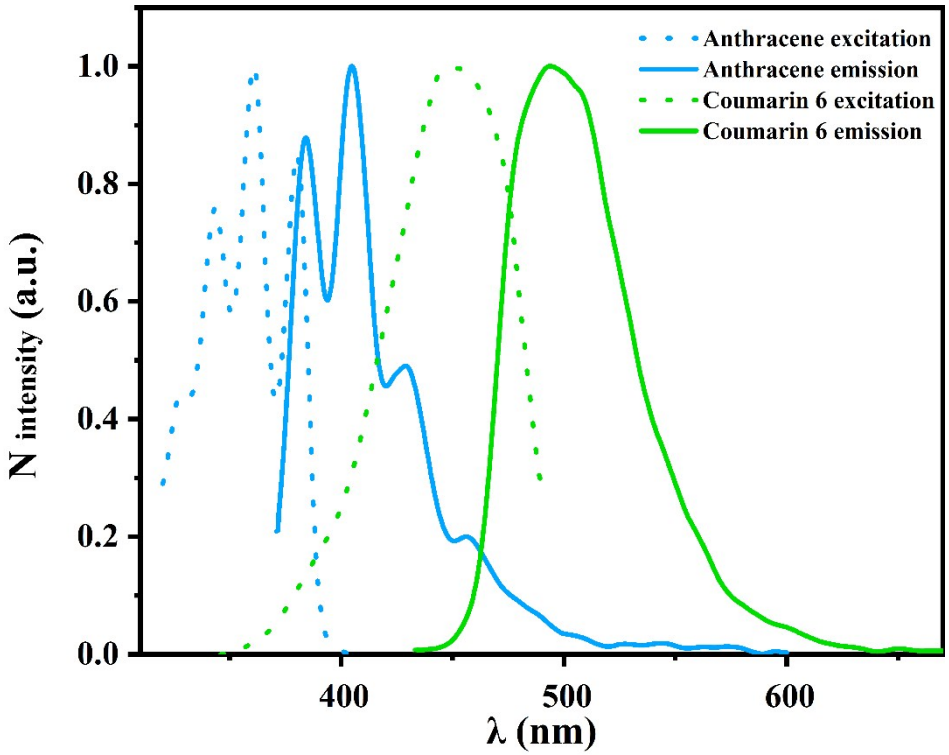

Fig.S1. Comparison of excitation and emission spectra of Anthracene and Coumarin 6.

We use confocal microscopy to observe the Anthracene and Coumarin 6 fluorescent nanoparticles morphology and their emission color. It confirms that the fluorescence was from the fabricated fluorescent nanoparticles. The images of split channels are presenting in Fig.S2.

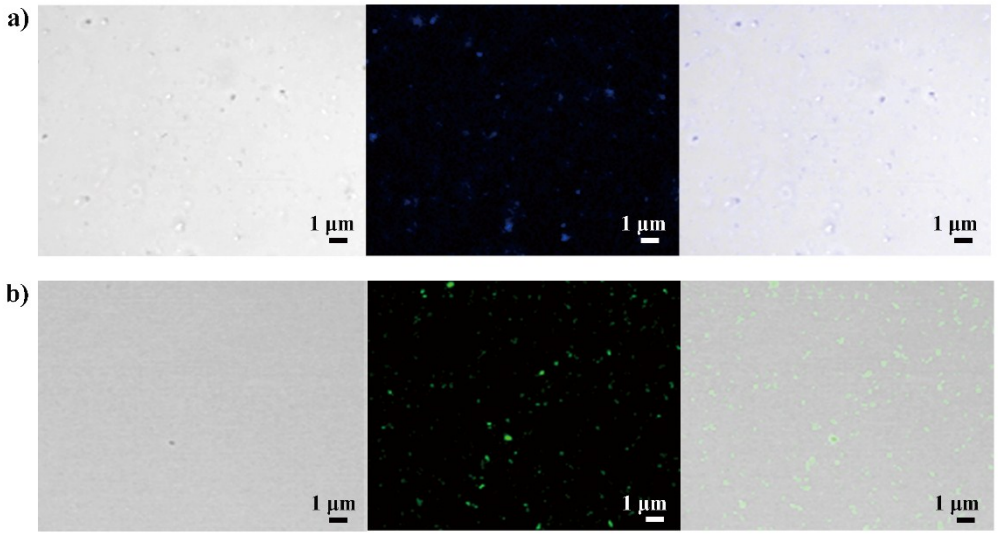

Fig.S2. a) The confocal microscopy images of Anthracene doped fluorescent nanoparticles; b) The confocal microscopy images of Coumarin 6 doped fluorescent nanoparticles. The left ones are bright field microscopy images. The ones in the middle are confocal microscopy images. The right ones are merged images of bright field and confocal microscopy to locate the emission spots.

As shown in Fig.S3a, common A4 paper ①, Dowling paper② and original paper ③ were compared under ultraviolet light excitation and ultraviolet light excitation. In addition, we wrote and compared on different sizes of paper using PS fluorescent nanoparticles suspension and the mixture of PS fluorescent nanoparticles and glycerol were used in order to verify the resolution of ink writing on paper (Fig.S3b, S3c, S3d).

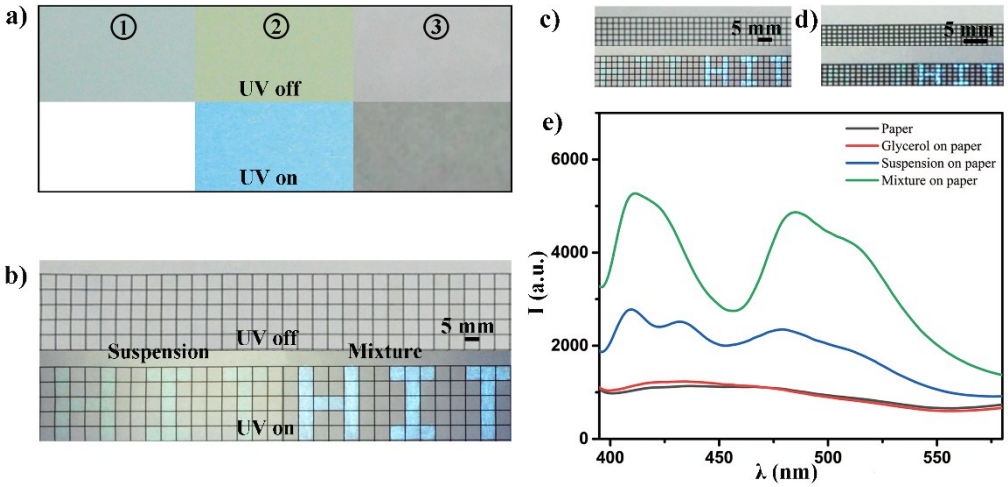

Fig.S3. Comparison of UV free and UV excited contrasts on different substrate. a) common A4 paper ①, Dowling paper② and original paper ③; b) The "HIT" logo is using as a pattern for printing test of suspension of PS fluorescent nanoparticles with/without addition of glycerol of resolution test of 5 mm; c) and d) are Resolution test of 2 mm and 1 mm; e) The fluorescence spectrum of different substrates.

The original paper without and with Anthracene nanoparticles and Coumarin 6 nanoparticles were observed under SEM as Fig.S4 shows.

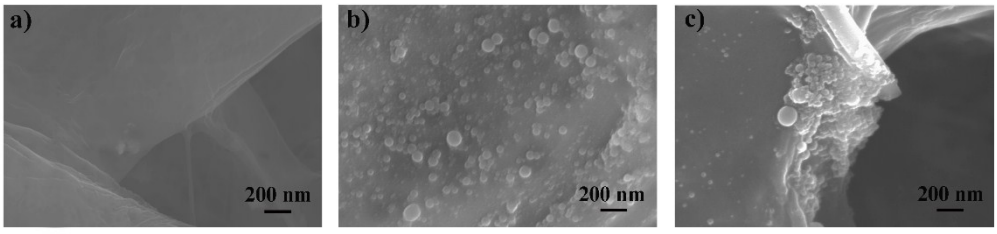

Fig.S4. Images of SEM. a) The original paper; b) The original paper with Anthracene nanoparticles; c) The original paper with Coumarin 6 nanoparticles.

The durability enhancement experiments are presented in Fig.S5.

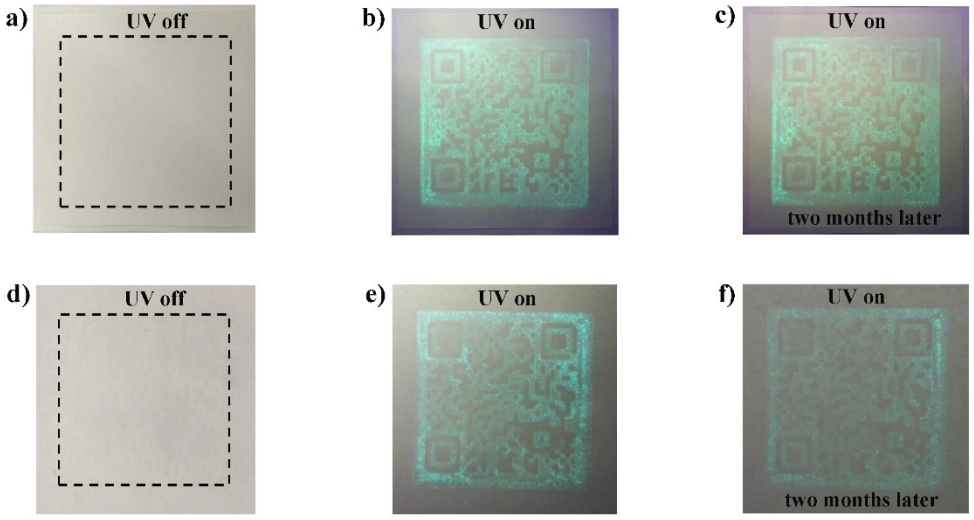

Fig.S5. a) The sample with sealed treatment; b) The sample with sealed treatment under UV excitation; c) The sample with sealed treatment under UV excitation after two months; d) The sample without sealed treatment; e) The sample without sealed treatment under UV excitation; f) The sample without sealed treatment under UV excitation after two months.

Ratios of molarity

The relative molar mass of Anthracene is 178.22, $M_{(Ant)} = 178.22\ g/mol$.
The relative molar mass of Coumarin 6 is 350.43, $M_{(Cou)} = 350.43\ g/mol$.
Let us take the 2 ml toluene solution in the "Experimental Process" section as an example. Dyes of 0.001 $_{wt}$ % was added to 2 ml of toluene solution.

$n = \frac{m}{M}$, $c = \frac{n}{V}$,we can get $c = \frac{m}{MV}$.

$c_{(Ant)} = \frac{m_{(Ant)}}{M_{(Ant)}V}$, $c_{Cou} = \frac{m_{(Cou)}}{M_{(Cou)}V}$, we can get $\frac{C_{(Ant)}}{C_{(Cou)}} = \frac{m_{(Ant)}M_{(Cou)}}{m_{(Cou)}M_{(Ant)}}$.

The total mass of the dye is m, $m = m_{Ant} + m_{Cou}$. m_{Ant} is the mass of Anthracene. m_{Cou} is the mass of Coumarin 6. n is amount of substance. c is molarity. V is volume of toluene solution.
When the mass ratio of Anthracene to Coumarin 6 dye is 99%:1%,

$$\frac{C_{(Ant)}}{C_{(Cou)}} = \frac{m_{(Ant)}M_{(Cou)}}{m_{(Cou)}M_{(Ant)}} = \frac{99 \times 350.43}{1 \times 178.22} \approx \frac{195}{1}$$.

Table list

Table S1. FRET efficiency calculation of samples of S1 series via fluorescent spectrum.

Sample	Anthracene: Coumarin 6 mass ratio (%)	Anthracene intensity peak (a.u.)	Coumarin6 intensity peak (a.u.)	FRET efficiency
S1_1	99:1	38863	7757	0.607
S1_2	95:5	19760	10687	0.855
S1_3	90:10	27537	16693	0.871
S1_4	85:15	27158	24645	0.914
S1_5	80:20	17793	19174	0.927
S1_6	75:25	14898	18200	0.936
S1_7	70:30	21484	48518	0.965
S1_8	65:35	13249	26886	0.961
S1_9	60:40	12944	28386	0.964
S1_10	55:45	10808	48273	0.982

Table S2. FRET efficiency calculation of samples of S1 series via fluorescent lifetime.

Sample	Lifetime(ns)	FRET efficiency
S1_1	2.776	0.001
S1_2	2.475	0.109
S1_3	2.508	0.097
S1_4	2.449	0.118
S1_5	2.415	0.131
S1_6	2.141	0.229
S1_7	2.051	0.261
S1_8	2.079	0.251
S1_9	2.089	0.248
S1_10	1.651	0.406

Table S3. FRET efficiency calculation of samples of S2 series via fluorescent spectrum.

Sample	The mass fractions of Anthracene: Coumarin 6 99%:1%	Anthracene intensity peak (a.u.)	Coumarin 6 intensity peak (a.u.)	FRET efficiency
S2_1	dye0.1wt%	14612	2739	0.582
S2_2	dye0.05wt%	19417	4940	0.692
S2_3	dye0.01wt%	21679	10272	0.835
S2_4	dye0.001wt%	32397	25949	0.902

Table S4. FRET efficiency calculation of samples of S2 series via fluorescent lifetime

Sample	S2_1	S2_2	S2_3	S2_4
Lifetime(ns)	2.776	2.742	2.064	2.373
FRET efficiency	0.001	0.013	0.257	0.109

Video list

Video S1 shows the invisibility of our samples without UV excitation. Video S2 shows our samples can be accessed and recognized under UV excitation. Video S3 shows that our samples with sealed treatment still be accessed and recognized under UV excitation. Video S4 shows that our sealed sample enhanced durability after two months.