Electronic Supplementary Material (ESI) for Dalton Transactions.
This journal is © The Royal Society of Chemistry 2019

Electronic Supplementary Information

Design of Novel Lanthanide-Doped Core-Shell Nanocrystals with Dual Up-conversion and Down-conversion Luminescence for Anti-counterfeiting Printing

Shaowen Xie,[a,c#] Guo Gong,[a#] Ya Song,[a] Haihu Tan,[a] Changfan Zhang,[a] Na Li,[a,b,d]

Yanxian Zhang,[c] Lijian Xu,[a,b,d] Jianxiong Xu,[a,b,d]* and Jie Zheng[c]

[a]*Hunan Key Laboratory of Biomedical Nanomaterials and Devices*
College of Life Sciences and Chemistry
Hunan University of Technology, Zhuzhou 412007, P. R. China

[b]*National & Local Joint Engineering Research Center of Advanced Packaging Materials Developing Technology, Hunan University of Technology, Zhuzhou, 412007, PR China*

[c]*Department of Chemical and Biomolecular Engineering*
The University of Akron, Akron, OH, 44325, USA

[d]*School of Materials Science and Energy Engineering*
Foshan University, Foshan, 528000, P. R. China

* To whom correspondence should be addressed. E-mail: (J.X.)

xujianxiong8411@163.com.

Contents

1. **Figure S1. Digital photographs of the dispersions of OA-CSNPs-GR in cyclohexane and free-CSNPs-GR in water.**
2. **Figure S2. (A) FT-IR spectra and (B) TGA characterization of OA-CSNPs-GR and free-CSNPs-GR.**
3. **Figure S3. Various pre-designed pattern, including: (A) peacock; (B) temple of heaven and (C) logo of "Hunan University of Technology".**
4. **Figure S4 Photographs of CSNPs-GR inks at indicated time periods under daylight, 254 nm and 980 nm excitation, respectively.**
5. **Table S1. Experimental formula for preparation of CSNPs-GR inks.**
6. **Table S2. Experimental results of viscosity test and surface tension test for Ink1-Ink6 CSNPs-GR inks.**
7. **Table S3. Experimental formula and experimental results of viscosity test and surface tension test for Ink7 (CSNPs-BG ink) and Ink8 (CSNPs-RB ink).**

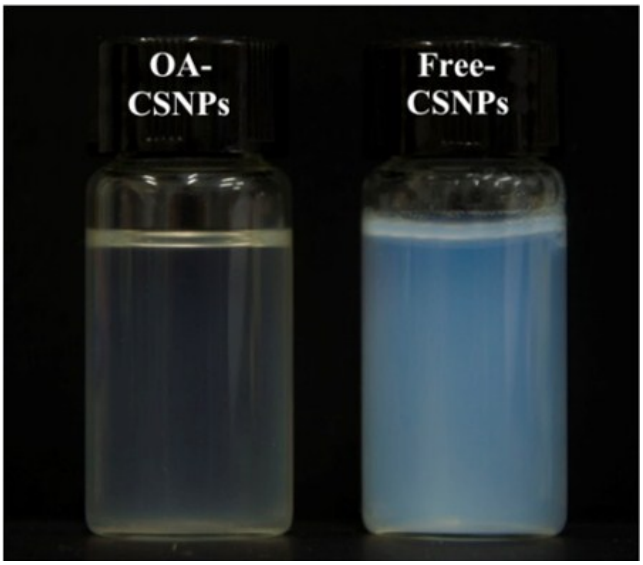

Figure S1. Digital photographs of the dispersions of OA-CSNPs-GR in cyclohexane and free-CSNPs-GR in water.

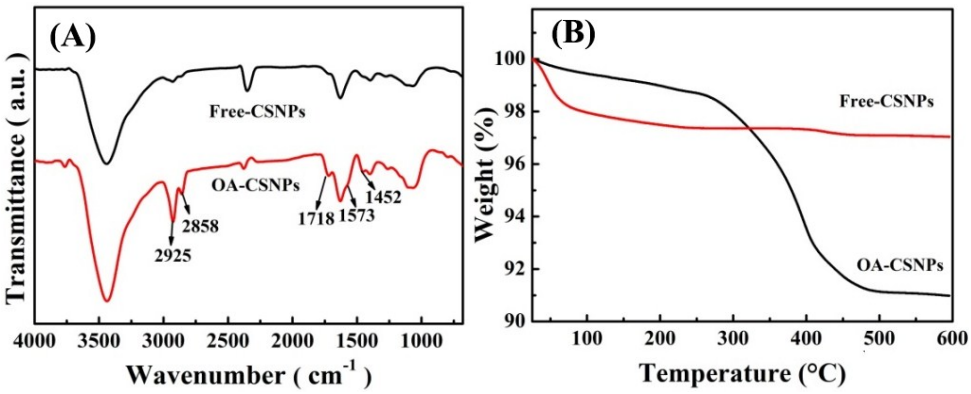

Figure S2. (A) FT-IR spectra and (B) TGA characterization of CSNPs-GR before and after removal of OA ligands.

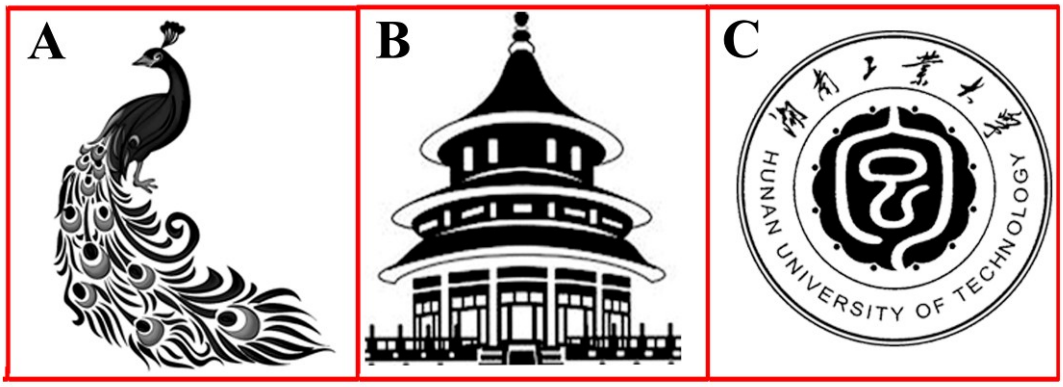

Figure S3. Various pre-designed pattern, including: (A) peacock; (B) temple of heaven and (C) logo of "Hunan University of Technology".

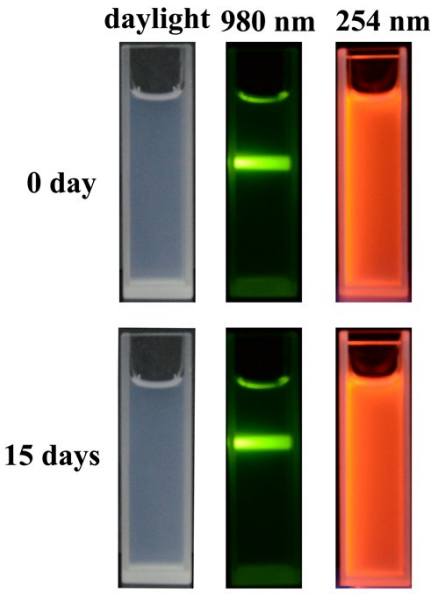

Figure S4 Photographs of CSNPs-GR inks at indicated time periods under daylight, 254 nm and 980 nm excitation, respectively.

Ink properties

To ensure inks work stably on the inkjet printer, the inks properties (*i.e.,* dynamic viscosity and surface tension) were tuned by evaluating the printing performance. Herein, we chose the preparation of the CSNPs-GR inks as a typical example. By fixing the weight ratio of CSNPs-GR (0.2 wt%) and changing the volume ratio of deionized water, ethanol and glycerol, a series of CSNPs-GR inks were formulated (sample Ink1-Ink6). The detail parameters of the preparation of Ink1-Ink6 were shown in Table S1. The properties of different CSNPs-GR inks were measured by evaluating the dynamic viscosity and surface tension, and their results were summarized in Table S2. Generally, the dynamic viscosity of inks has a critical impact on the flow properties in the cartridge and through the nozzle. Such as, high viscosity inks may induce the nozzle to clog, while low viscosity inks will cause damped oscillation and infiltration resulting in an unsuitable precision of printing. In addition, an appropriate surface tension of inks is beneficial to form a relatively small contact angle between the substrates and droplet, which increases the coverage area for a single inks droplet to fabricate pattern with good uniformity under certain dots per inch dpi of a printer. The preferred dynamic viscosity and surface tension of inks for the inkjet printer may vary within a specific range at room temperature: the dynamic viscosity varies from 1 to 5 mPa·s, while the surface tension varies from 30 to 60 mN/m. Based on the results in Table S2, we selected the Ink5 as the optimized ink, where the dynamic viscosity and surface tension were 3.510 mPa·s and 35.156 mN/m, respectively. By keeping the mass ratio of CSNPs-BG (0.8 wt%) and CSNPs-

RB (1.0 wt%), respectively, another two CSNPs inks with proper dynamic viscosity and surface tension were prepared (Table S3).

Table S1. Experimental formula for preparation of CSNPs-GR inks.

Sample	CSNPs-GR (wt%)	Deionized water (wt%)	Ethanol (wt%)	Glycerol (wt%)
Ink1	0.2	20.0	20.0	60.0
Ink2	0.2	30.0	20.0	50.0
Ink3	0.2	20.0	40.0	40.0
Ink4	0.2	40.0	20.0	40.0
Ink5	0.2	40.0	40.0	20.0
Ink6	0.2	40.0	50.0	10.0

Table S2. Experimental results of viscosity test and surface tension test of Ink1-Ink6 CSNPs-GR inks.

Sample	Viscosity test					Surface tension test				
	t (s)	c (mm^2/s^2)	v (mm^2/s)	ρ (g/cm^3)	η (mPa·s)	h (m)	r (m)	r_1 (m)	r_2 (m)	γ (mN/m)
Ink1	3215	0.00589	18.936	1.154	21.853	0.0138	0.0005	0.02490	0.00057	38.676
Ink2	1790	0.00589	10.543	0.968	10.206	0.0125	0.0005	0.02500	0.00059	29.425
Ink3	1480	0.00589	8.717	0.996	8.682	0.0127	0.0005	0.02500	0.00058	30.754
Ink4	960	0.00589	5.654	1.035	5.852	0.0110	0.0005	0.02490	0.00058	27.734
Ink5	628	0.00589	3.698	0.949	3.510	0.0146	0.0005	0.02500	0.00055	35.156
Ink6	512	0.00589	3.015	0.909	2.741	0.0129	0.0005	0.02500	0.00055	28.505

Table S3. Experimental formula and experimental results of viscosity test and surface tension test of Ink7 (CSNPs-BG ink) and Ink8 (CSNPs-RB ink).

Sample	CSNPs (wt%)	Deionized water (wt%)	Ethanol (wt%)	Glycerol (wt%)
Ink7	0.8	40.0	40.0	20.0
Ink8	1.0	40.0	40.0	20.0

Sample	Viscosity test					Surface tension test				
	t (s)	c (mm^2/s^2)	v (mm^2/s)	ρ (g/cm^3)	η (mPa·s)	h (m)	r (m)	r_1 (m)	r_2 (m)	γ (mN/m)
Ink7	620	0.0059	3.651	0.945	3.451	0.0148	0.0005	0.0250	0.00058	34.415
Ink8	625	0.0059	3.681	0.939	3.457	0.0143	0.0005	0.0250	0.00058	33.054