Supporting Information

Electrostatically Assembled Carbon Dots/Boron Nitride Nanosheets Hybrid Nanostructures for Thermal Quenching-Resistant White Phosphors

Shuai Cheng, ‡[a] Tengyang Ye, ‡[a] Huiwu Mao,[a] Yueyue Wu,[c] Wenjie Jiang,[b] Chaoyi Ban,[a] Yuhang Yin,[a] Juqing Liu,*[a] Fei Xiu*[a] & Wei Huang*[a, b]

[a]Key Laboratory of Flexible Electronics (KLOFE) & Institute of Advanced Materials (IAM), Nanjing Tech University (NanjingTech), 30 South Puzhu Road, Nanjing 211816, China.
E-mail: iamjqliu@njtech.edu.cn; iamfxiu@njtech.edu.cn; wei-huang@njtech.edu.cn

[b]Shaanxi Institute of Flexible Electronics (SIFE), Northwestern Polytechnical University (NPU), 127 West Youyi Road, Xi'an 710072, China.

‡These authors contributed equally.

Experimental Section

Materials

All reagents are used as received without further purification. Anhydrous citric acid (CA, ≥97%) and 1-hexadecylamine (HDA, ≥95%) are purchased from Tixiai (Shanghai) Chemical Company. Polydimethylsiloxane (PDMS, SYLGARD 184 SILICONE ELASTOMER) is purchased from Shanghai Deji Trading corporation. Dimethylbenzene (≥90%) is purchased from Aladdin Industrial Corporation. Chloroform (≥99.0%) is purchased from Shanghai Lingfeng Chemical Reagent Corporation. Sodium hydroxide (NaOH, ≥85%) is purchased from Xilong Scienctific. Potassium hydroxide (KOH, ≥96.0%) is purchased from Sinopharm Chemical Reagent Co., Ltd. Hexagonal boron nitride (h-BN, 99.9%) is purchased from Aladdin Industrial Corporation.

Preparation of white emissive C-dots

White emissive C-dots are synthesized by a pyrolytic treatment of CA and HDA. Typically, 0.5 g of CA and 0.75 g HAD is dissolved in 10 mL of dimethylbenzene and then sonicated (Elma Schmidbauer GmbH, Germany) for 15 min to obtain a homogeneous solution. Then the solution is transferred to a poly(tetrafluoroethylene) (Teflon)-lined autoclave (25 mL) and heated at 180 ºC for 12 h. After reaction, the obtained sample is cooled down to the room temperature and stands for 24 h, followed by filtering the supernatant to get C-dots solution.

Preparation of BNNS

BNNS are prepared basing on a previously reported method. Firstly, 2.84 g of NaOH, 2.16 g of KOH and 1.0 g of h-BN powder are mixed and then further ground into a homogeneous form. The obtained powder is evenly transferred to four 25 mL poly(tetrafluoroethylene) (Teflon)-lined autoclave. The sealed autoclaves are heated and kept at 180 °C for 2 h. After cooling down to room temperature, the solid product is collected from the autoclaves and dispersed into 300 mL deionized water. The dispersion is sonicated for 1 h. Subsequently the sample is filtered, re-dispersed in deionized water, and centrifuged to remove hydroxides and other unreacted materials. Finally, the stable aqueous dispersions of BNNS with the size of 200-300 nm are dried in a vacuum oven under 80 for 12 h to obtain BNNS powder.

Preparation of C-dots/BNNS phosphors

Firstly, 3 mg of the as-prepared BNNS powder is suspended in 8 mL of chloroform. Under magnetic stirring, 5 mL of C-dots chloroform solution (contains 10 mg C-dots gel) is added. The zeta-potential measurements prove that the mean zeta-potential of C-dots solution is positive (7.97 mV) (Table S1), while that of BNNS solution is negative (-25.39 mV) (Table S2). Thus, through electrostatic interactions between positively charges of C-dots and negatively charges of BNNS, C-dots are electrostatically assembled on to the surface of BNNS. Finally, the C-dots/BNNS hybrids which emit bright white color under UV light are obtained by a further drying process in vacuum oven at 50 °C.

Preparation of C-dots and C-dots/BNNS-WLED

As displayed in Figure 1, for the preparation of C-dots/BNNS-WLED, 0.3 g of C-dots/BNNS hybrids in 5 mL of chloroform solution and 1 g of polydimethylsiloxane (PDMS, Shanghai JIDE Commercial Trading Company) are mixed and stirred for 20 min to be dispersed uniformly. Chloroform and bubbles introduced during the stirring process are removed by applying alternating cycles of vacuum. Then the mixed gel is coated onto the surface of LED chip, followed by a curing process in vacuum oven at 70 °C for 1.5 h. Moreover, the C-dots WLED without BNNS is also prepared for contrast experiment. First, 5 mL of C-dots chloroform solution are mixed with 1 g of

PDMS. Then, the mixture is heated at 65 °C to remove the chloroform completely and finally coated onto the LED chip to obtain the LED device.

Characterization

Transmission electron microscopy (TEM) images are taken on a HITACHI 7605 microscope and the high resolution transmission electron microscopy (HRTEM) images are taken on a JEOL 2100F microscope. The morphology images and elemental mapping images are measured by scanning electron microscope (SEM, JSM 7800F). The Photoluminescence (PL) spectra are recorded by a Fluorescence Spectrometer (F-4600). X-ray photoelectron spectroscopy (XPS, Thermo escalab 250Xi) is used to confirm elements and chemical composition of C-dots. Transform Infrared Spectroscopy (FTIR, DT-40) is used to confirm the functional groups of C-dots. The related photoelectric parameters of LEDs are measured by a spectrophotometer (PR-745). The fluorescence decay curves are measured with Transient State Fluorescence Spectrometer (Edinburgh Instruments FLS 980). The surface charge of the C-dots and BNNS solution is measured by using a zeta/nano particle analyzer (NanoPlus, X11-15297).

Table S1. Zeta Potential of C-dots.

NO.	Cell Position	Mobility (cm^2/Vs)	Zeta Potential (mV)	Zeta Potential Average (mV)
1	0.7 (6.255mm)	-4.422e-006	-3.31	
2	0.35 (6.08mm)	2.585e-005	19.32	
3	0 (5.905mm)	9.512e-006	7.11	7.97
4	-0.35 (5.73mm)	9.512e-007	0.71	
5	-0.7 (5.555mm)	2.122e-005	15.86	

Table S2. Zeta Potential of BNNS.

NO.	Cell Position	Mobility (cm^2/Vs)	Zeta Potential (mV)	Zeta Potential Average (mV)
1	0.7 (6.045mm)	-6.119e-005	-45.74	
2	0.35 (5.87mm)	-3.328e-005	-24.88	
3	0 (5.695mm)	-1.698e-005	-12.69	-25.39
4	-0.35 (5.52mm)	-2.021e-005	-15.11	
5	-0.7 (5.345mm)	-3.820e-005	-28.55	

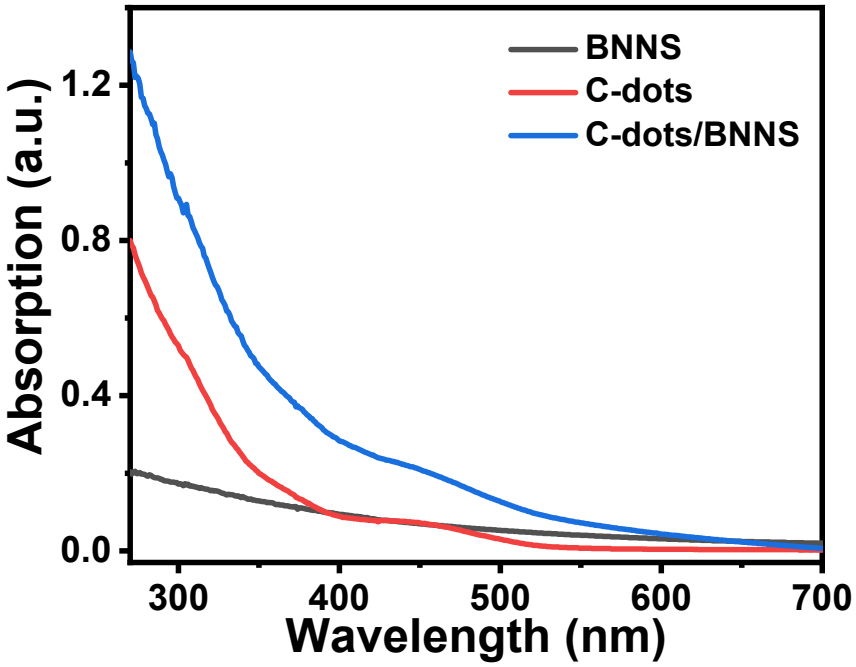

Fig. S1. UV-Vis spectra of BNNS, C-dots, and C-dots/BNNS solutions.

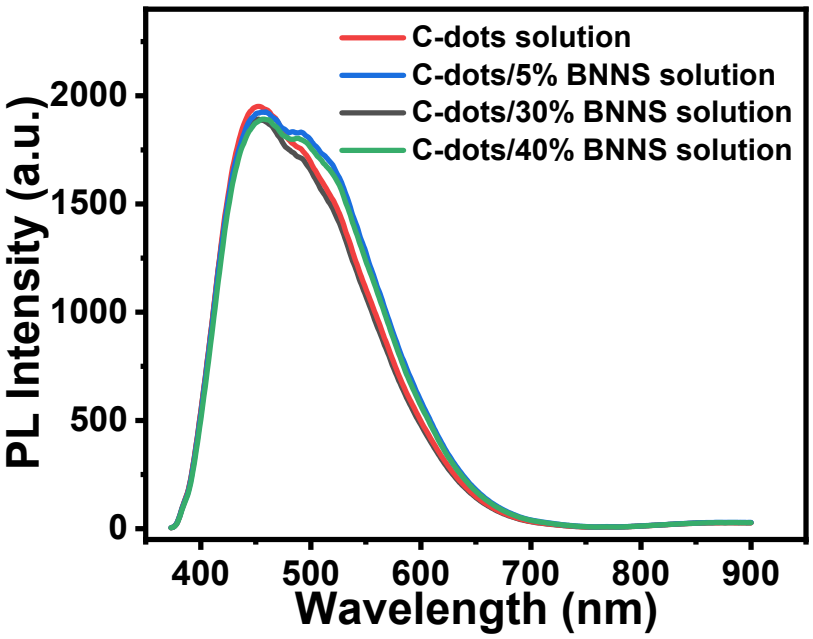

Fig. S2. PL spectra of C-dots solution, C-dots/5%BNNS, C-dots/10%BNNS, C-dots/30%BNNS and C-dots/40%BNNS hybrid solution under 380 nm excitation.

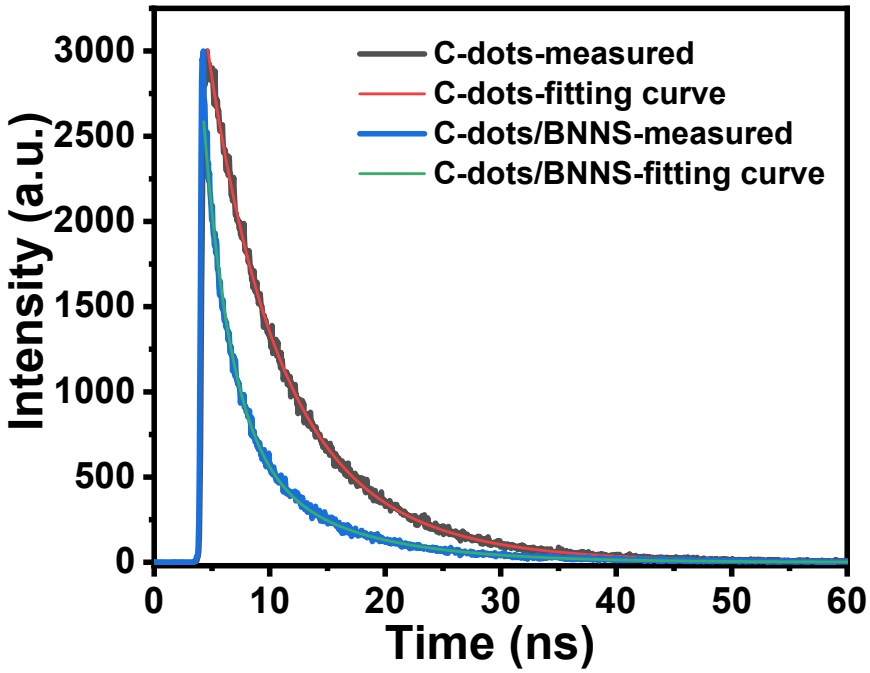

Fig. S3. TRPL decay curves of the C-dots and C-dots/BNNS hybrid solution.

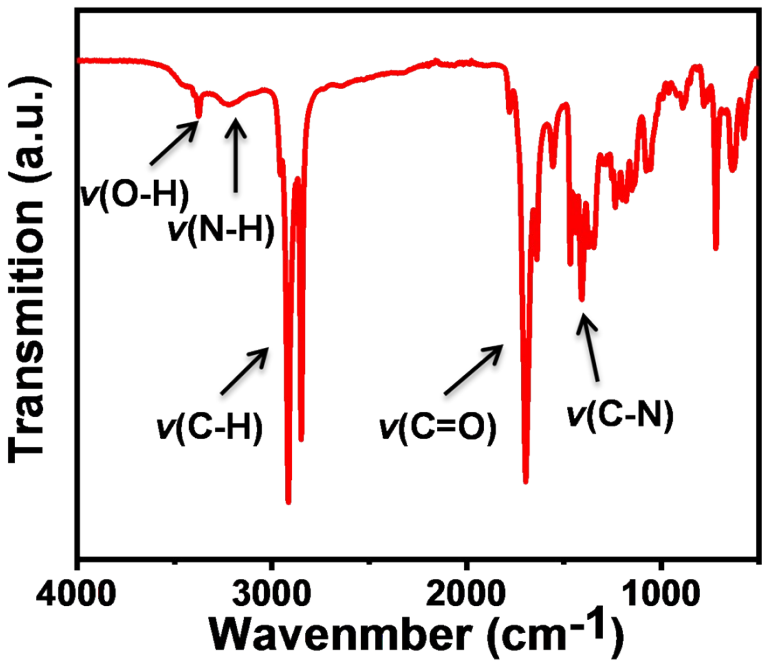

Fig. S4. FT-IR spectra of C-dots.

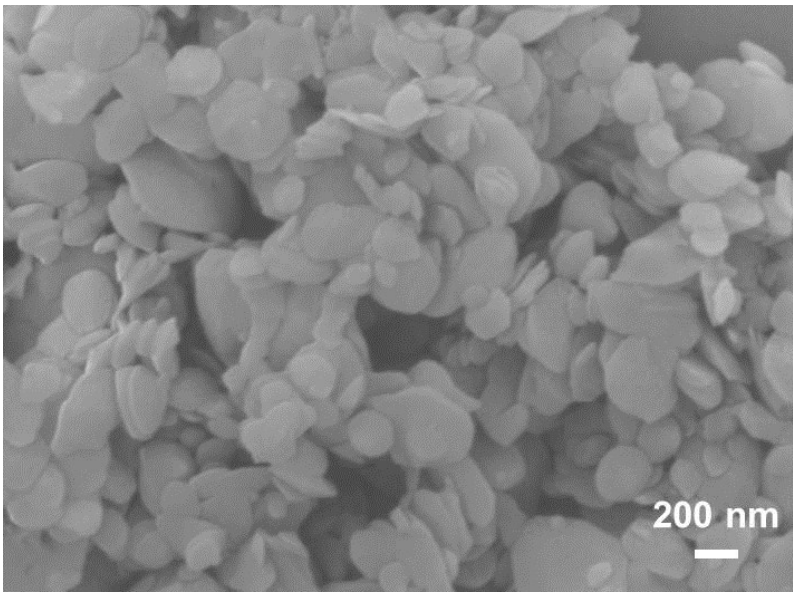

Fig. S5. SEM image of BNNS.

Table S3. Elemental analysis of C-dots/BNNS hybrid

Element	wt%
B	34.31
C	13.41
N	49.05
O	3.24
Sum:	100.00

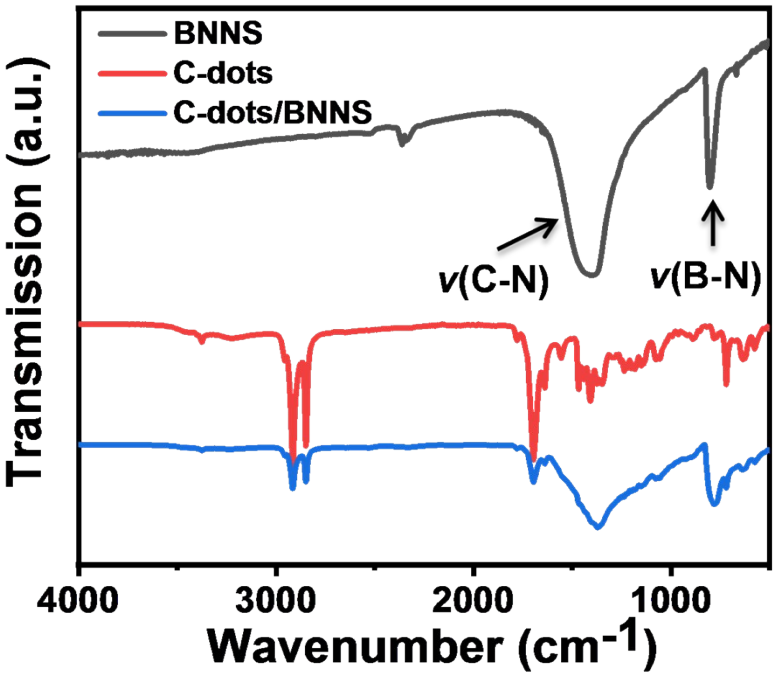

Fig. S6. FT-IR spectra of BNNS, C-dots and BNNS/C-dots hybrid.

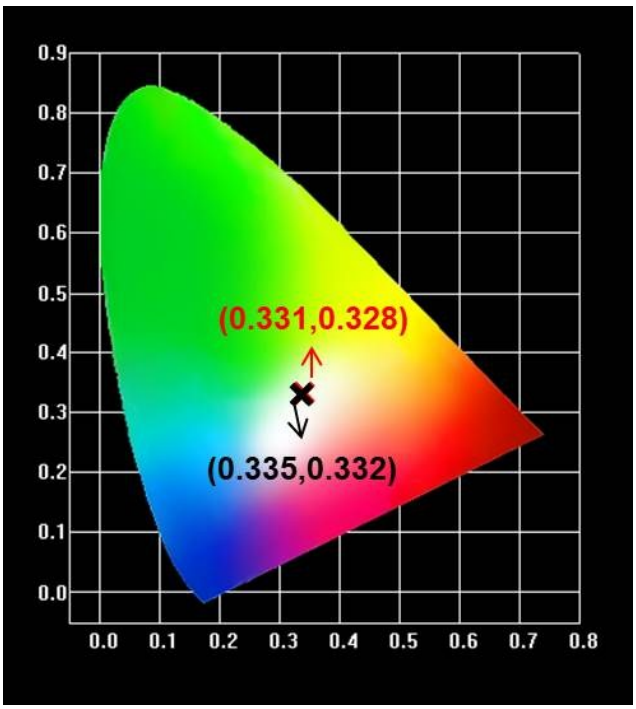

Fig. S7. The corresponding CIE chromaticity diagram.