K/Na Co-Doped Carbon Nitride: A Robust Luminescent Material with High Thermal Endurance and UV Durability

Jian Luo[1,2], Chenkai Jin[1], Juan Cai[1], Yan Lei[1], Juncheng Huang[2,], Chao Fang[2], Lixin Song[1,*], Haining Na[1,2,*], Jin Zhu[2]*

1. School of Materials Science and Engineering, Shenyang University of Chemical Technology, Shenyang, Liaoning 110142, China

2. Key Laboratory of Bio-Based Polymeric Materials of Zhejiang Province, Ningbo Institute of Materials Technology and Engineering, Chinese Academy of Sciences, Ningbo, Zhejiang 315201, China

**Corresponding Author: nahaining@nimte.ac.cn; fengchengqi@nimte.ac.cn;*

Tel: +86-574-86689806; Fax: +86-574-86685186.

Figure captions

Figure S1. (a–c) Effects of temperature, reaction time, and atmosphere on CN-K/Na structure. (d) Impact of ultrasonication on structural evolution.

Figure S2. (a–c) PL intensity variations under different synthesis conditions. (d) Effect of doping ratio on PL emission.

Figure S3. (a–c) XPS spectra of pristine CN. (d) Raman spectrum of pristine CN.

Figure S4. (a) Density of states. (b) Simulated band structure of CN-K/Na.

Figure S5. (a) SEM image of pristine C_3N_4. (b) SEM after 1 h ultrasonication. (c) Zeta potential changes. (d) DLS particle size distribution before and after treatment.

Figure S6. TRPL lifetimes under different UV irradiation times.

Figure S7. Structural changes in PMMA with varying CN-K/Na content.

Figure S8. PL intensity of composites with different CN-K/Na amounts.

Figure S9. PL spectra of composites after UV aging for (a) 96 h and (b) 144 h with different CN-K/Na amounts.

Figure S10. PL spectra of composites with different CN-K/Na amounts (a) 5 mg, (b) 10 mg, and (c) 20 mg under UV irradiation for 0 h, 48 h, 96 h, and 144 h.

Table S1. CIE chromaticity coordinates at various temperatures.

Table S2. Atomic composition ratios after different UV exposure durations.

Table S3. CIE coordinates after various UV irradiation durations.

Table S3. Comparison of Photoluminescence Intensity Retention of Representative Phosphors at Different Temperatures.

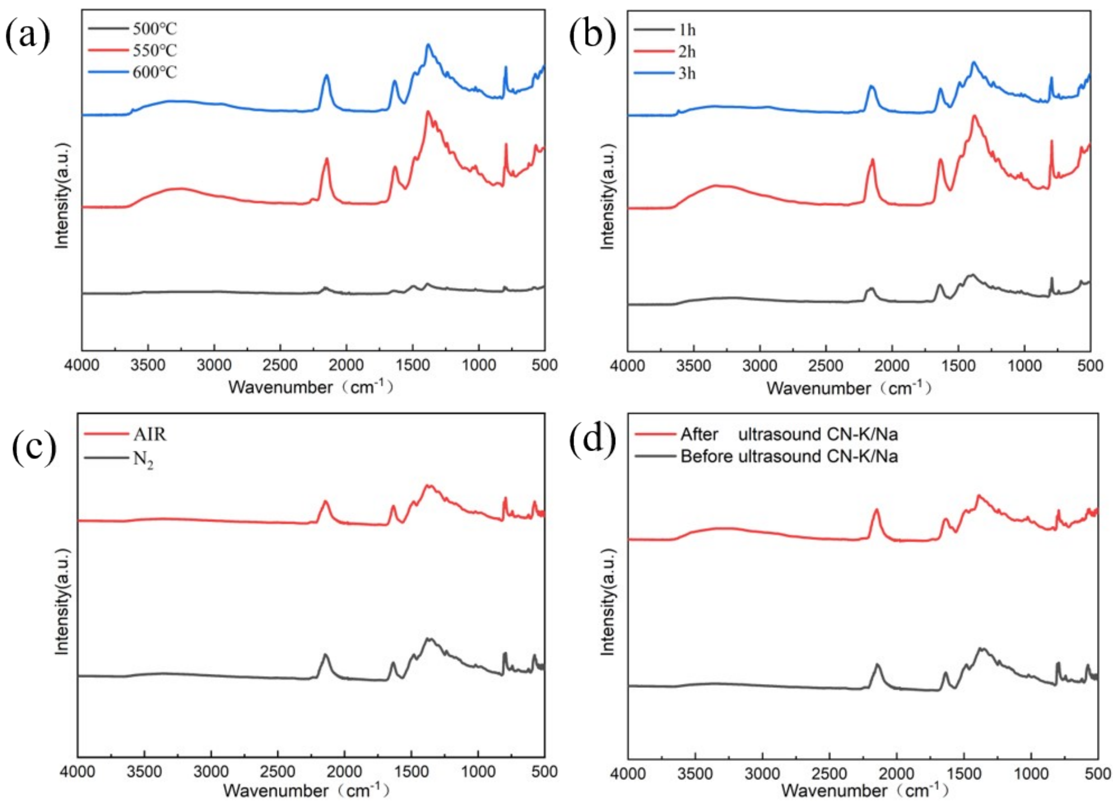

Figure S1. (a–c) Effects of temperature, reaction time, and atmosphere on CN-K/Na structure. (d) Impact of ultrasonication on structural evolution.

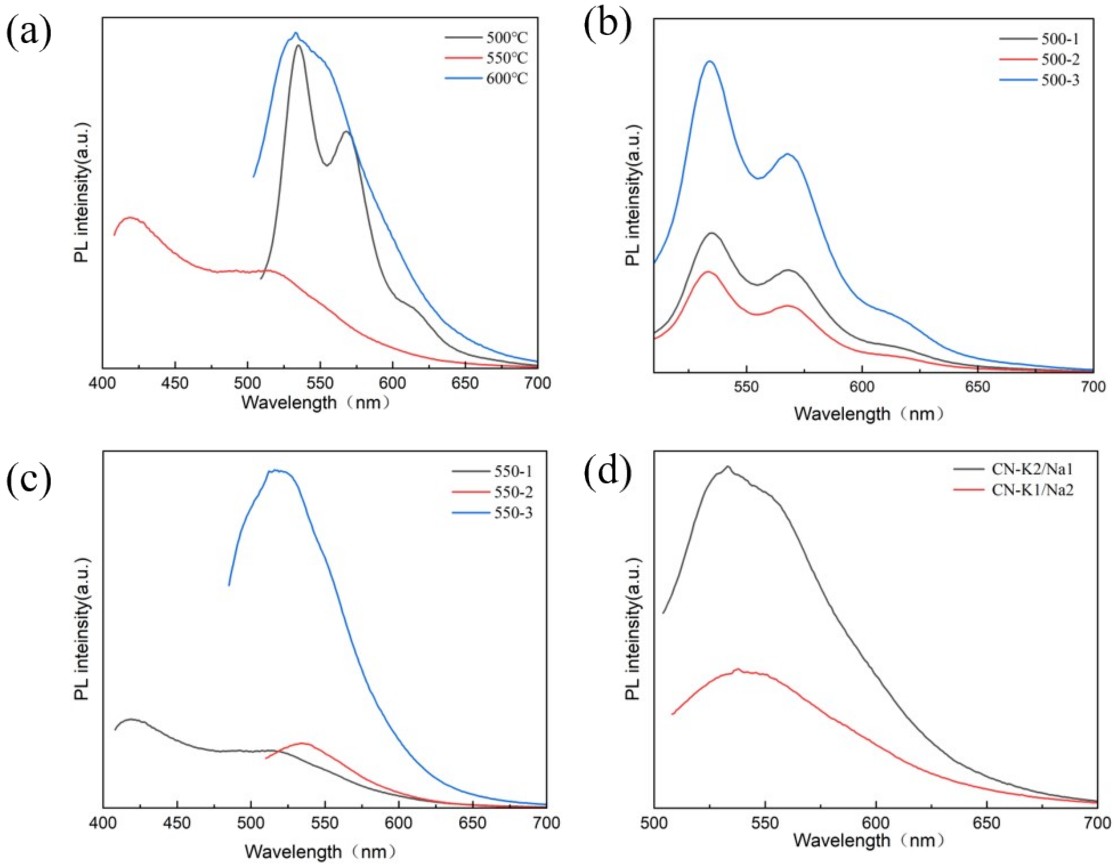

Figure S2. (a–c) PL intensity variations under different synthesis conditions. (d) Effect of doping ratio on PL emission.

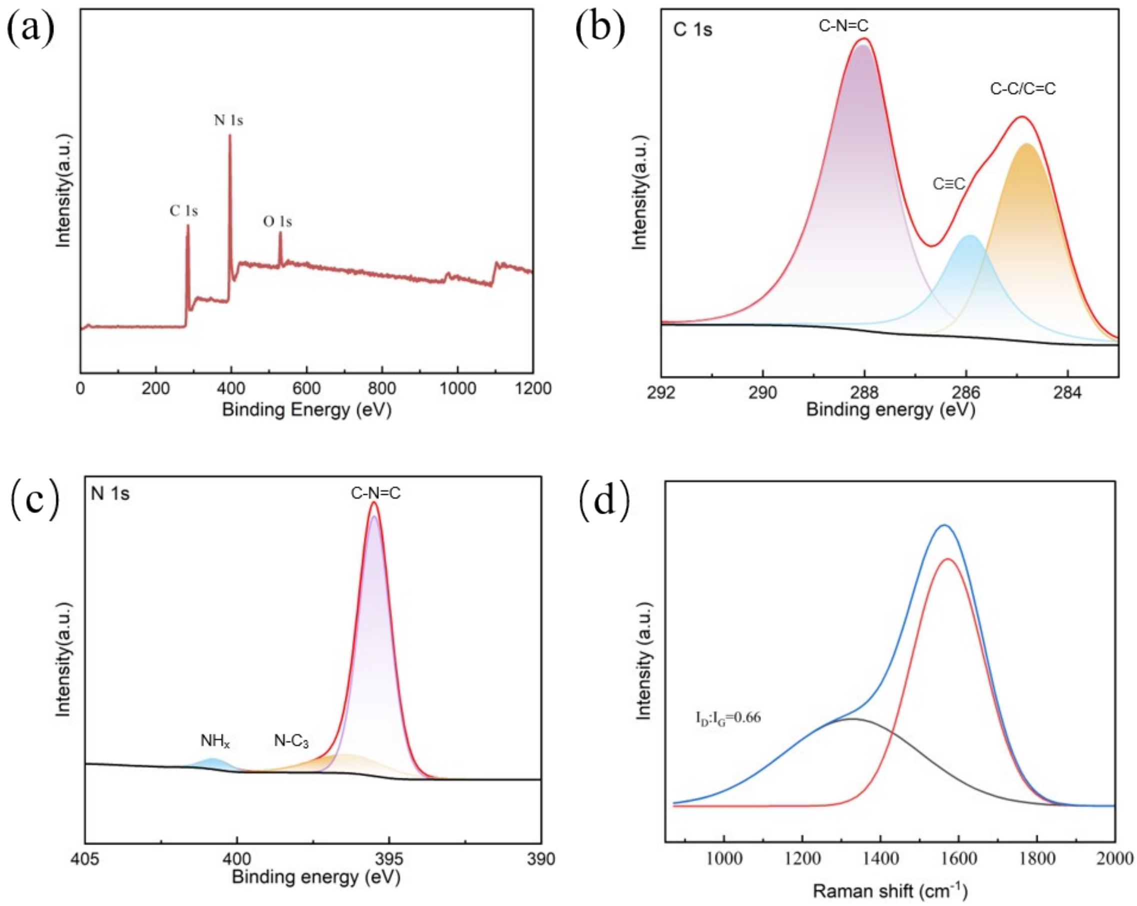

Figure S3. (a–c) XPS spectra of pristine CN. (d) Raman spectrum of pristine CN.

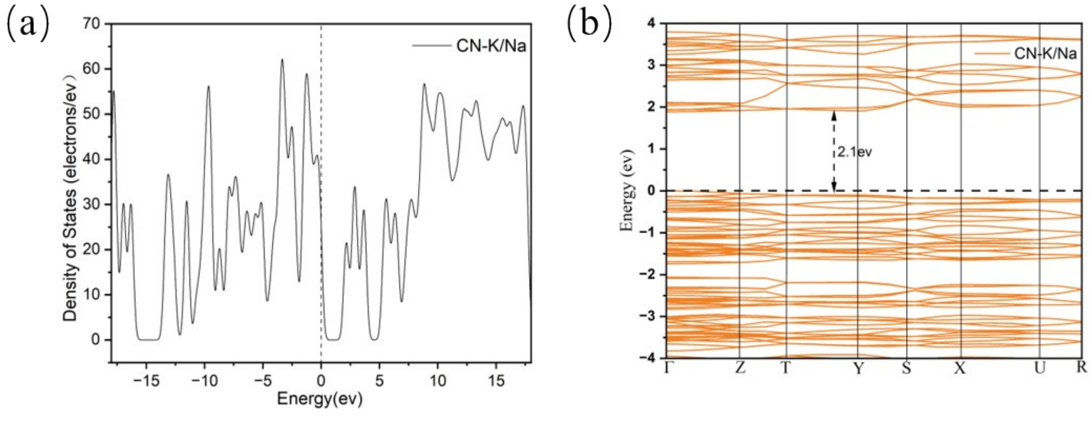

Figure S4. (a) Density of states. (b) Simulated band structure of CN-K/Na.

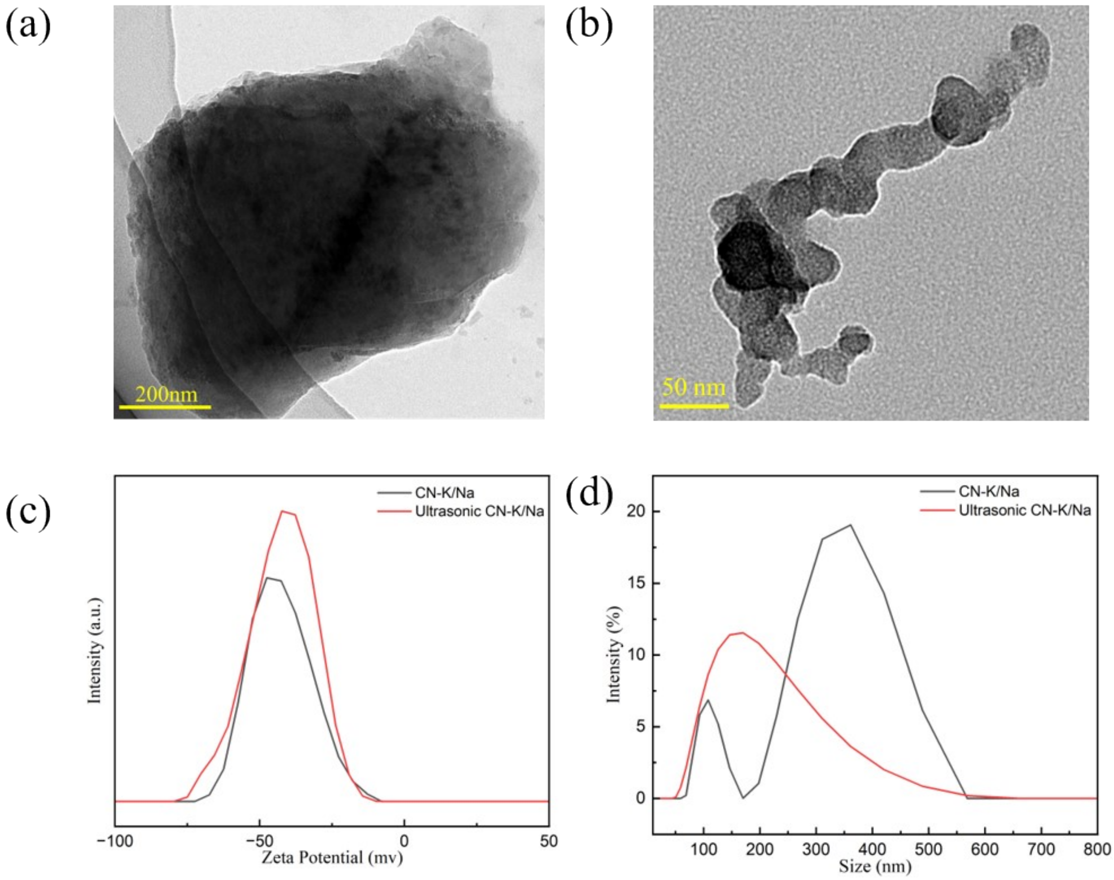

Figure S5. (a) SEM image of pristine C_3N_4. (b) SEM after 1 h ultrasonication. (c) Zeta potential changes. (d) DLS particle size distribution before and after treatment.

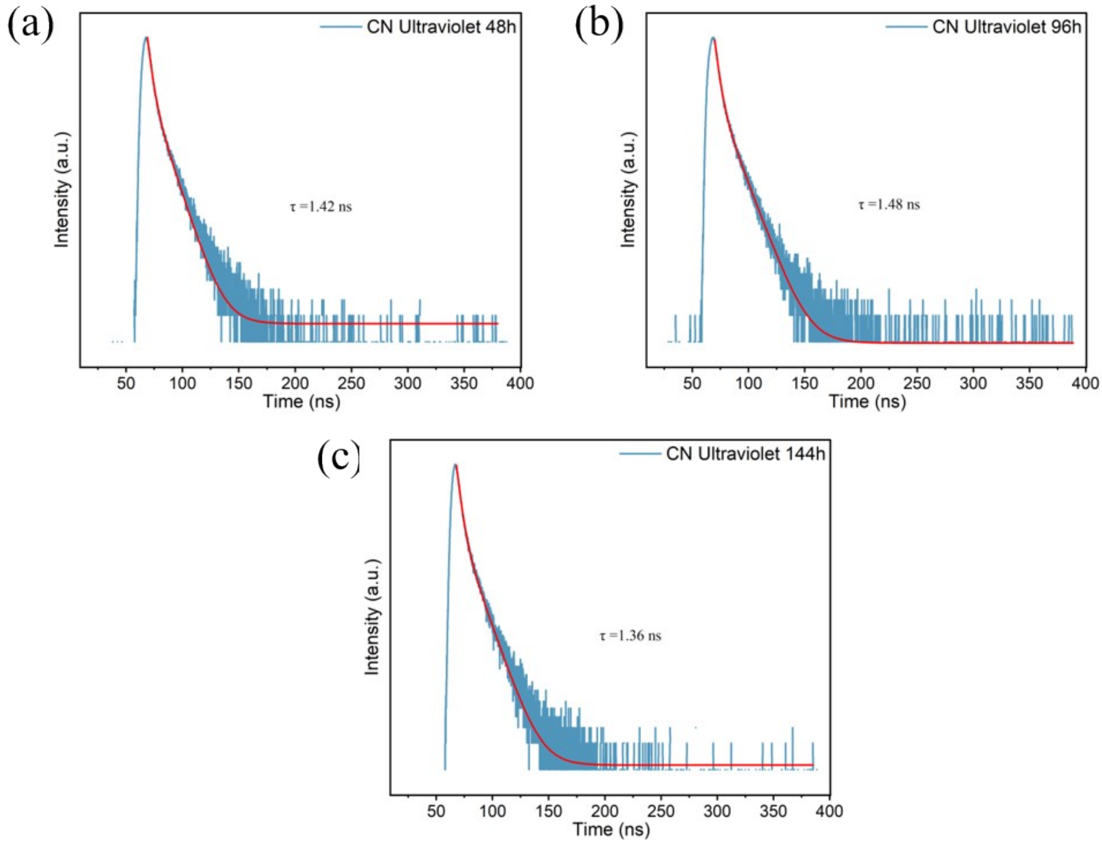

Figure S6. TRPL lifetimes under different UV irradiation times

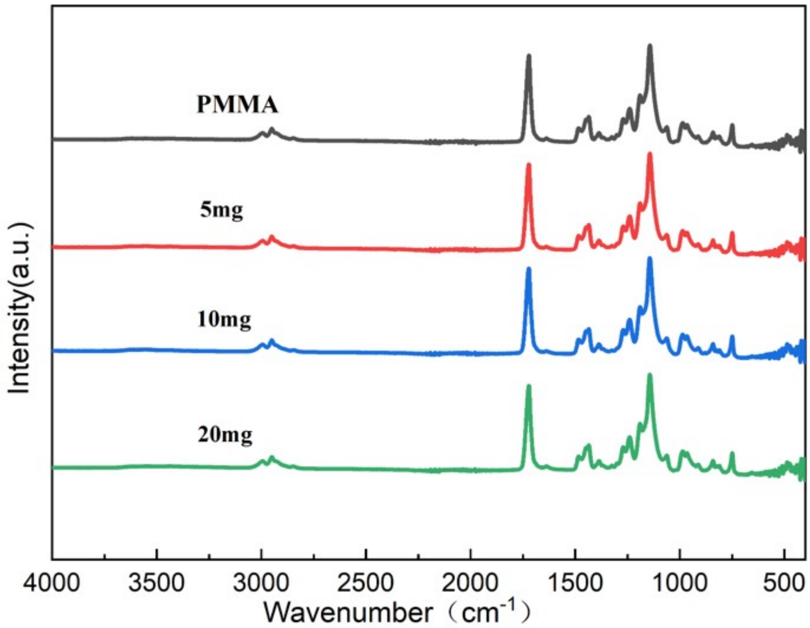

Figure S7. Structural changes in PMMA with varying CN-K/Na content.

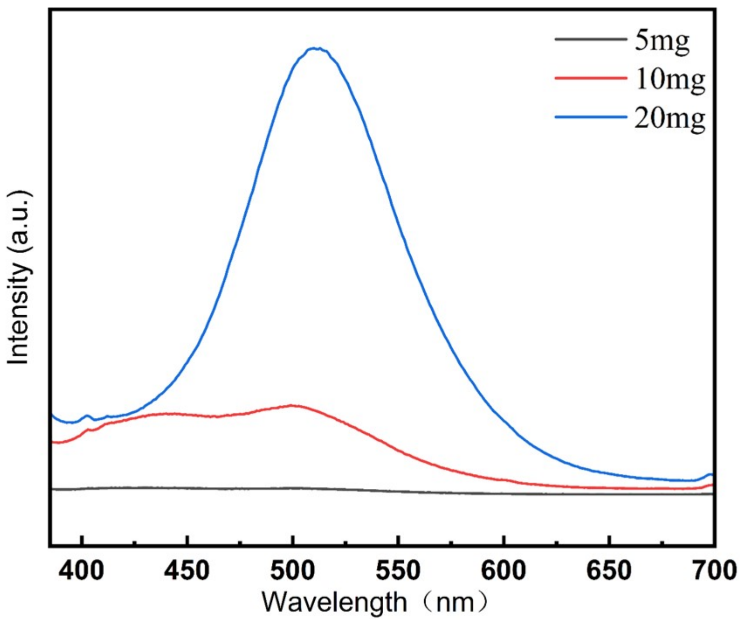

Figure S8. PL intensity of composites with different CN-K/Na amounts.

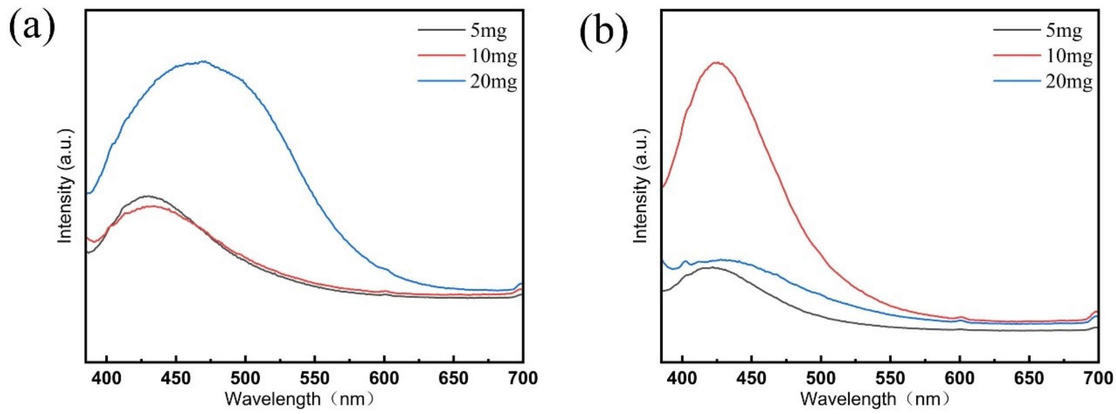

Figure S9. PL spectra of composites after UV aging for (a) 96 h and (b) 144 h with different CN-K/Na amounts.

Figure S10. PL spectra of composites with different CN-K/Na amounts (a) 5 mg, (b) 10 mg, and (c) 20 mg under UV irradiation for 0 h, 48 h, 96 h, and 144 h.

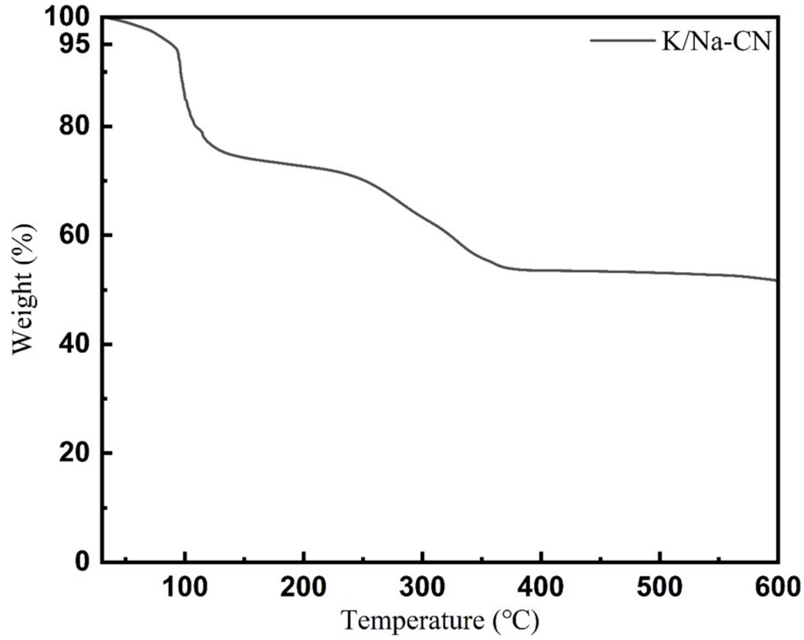

Figure S11.In situ Thermogravimetric Analysis (TGA) of K/Na Co-doped Carbon Nitride During Synthesis

Table S1. CIE chromaticity coordinates at various temperatures.

Temperature (k)	x	y
298	0.2948	0.5849
323	0.2930	0.5830
348	0.2926	0.5826
373	0.2925	0.5826
398	0.2928	0.5829
423	0.2936	0.5834
448	0.2946	0.5841
473	0.2956	0.5850
498	0.2974	0.5859
523	0.2992	0.5870
548	0.3014	0.5880
573	0.3036	0.5889
598	0.3058	0.5897
623	0.3080	0.5904

Table S2. Atomic composition ratios after different UV exposure durations.

Time (h)	**T_1 (10^{-10} s)**	**B_1**	**T_2 (10^{-10} s)**	**B_2**	**T_3 (10^{-10} s)**	**B_3**
0	8.75	2300.21	34.38	626.99	\	\
48	9.45	2534.13	34.63	585.14	\	\
96	8.86	2072.93	33.51	652.94	\	\
144	27.71	457.71	31.74	2074.39	39.77	175
192	9.55	-114555.3	9.53	116862.7	31.88	613.97

Table S3. CIE coordinates after various UV irradiation durations.

Time (h)	**x**	**y**
0	0.33522	0.48731
48	0.30621	0.45192
96	0.31037	0.47347
144	0.32361	0.47816
192	0.32323	0.48309

Table S4. Comparison of Photoluminescence Intensity Retention of Representative Phosphors at Different Temperatures

Samples	**Temperature (K)**	**PL Intensity Retention (%)**	**Refs.**
YAG:Ce^{3+}	423	89	[1]
MgO:Cr^{3+},Ni^{2+}	423	83	[2]
YAGG:Cr^{3+}	423	92.36	[3]
Li_2BaSiO_4:Eu^{2+}	473	63	[4]
$K_2Sr_{1.25}Ba_{0.75}(PO_4)_2$:$Eu^{2+}$	473	93	[5]
$CsPbBr_3$@m-SiO_2	423	88.1	[6]
$CsPbBr_3$@Kaolin	373	82.8	[7]
$SrLiAl_3N_4$:Eu^{2+}	423	80	[8]
Mn^{4+}-doped K_2GeF_6	400	70	[9]
Mn^{4+}-doped K_2TiF_6 / K_2SiF_6 / other fluorides	462	50	[10]
Mn^{4+}-doped K_2SiF_6	500	50	[11]
$NaLaMgWO_6$:0.02Tm^{3+},0.04Dy^{3+}	473	77.9	[12]
$K_3Gd(PO_4)_2$:0.01Tm^{3+},0.08Dy^{3+}	498	45	[13]
$Ca_8ZnLa(PO_4)_7$:0.01Tm^{3+},0.1Dy^{3+}	423	84.5	[14]
$Ba_3La_6(SiO_4)_6$:0.075Tm^{3+},0.1Dy^{3+}	423	77	[15]
$Li_3Ba_2Gd_3(WO_4)_8$:0.03Tm^{3+},0.12Dy^{3+}	423	82.5	[16]

$KBaIn_2(PO_4)_3{:}0.05Tm^{3+},0.05Dy^{3+}$	423	80.5	[17]
CN-K/Na	**473**	**90.8**	**This Work**
CN-K/Na	**623**	**75**	

References

[1] H.-J. Li, Q.-Y. Shao, Y. Dong, J.-Q. Jiang, C. Liang, J.-H. He, *Chinese J. Luminescence* 2008, 29, 984–988.

[2] B.-M. Liu, X.-X. Guo, L.-Y. Cao, L. Huang, R. Zou, Z. Zhou, J. Wang, *Chemical Engineering Journal* 2023, *452*, 139313.

[3] Z. Yue, D. Sun, Z. Lyu, S. Shen, C. Lyu, P. Luo, H. You, *J. Mater. Chem. C* 2023, *11*, 16563.

[4] X. Zhang, J. Su, X. Yan, Y. Liao, Z. Wu, C. Zhou, *Solid State Sciences* 2020, *99*, 106050.

[5] T. Yang, T. Zhang, S. Huang, T. D. Christopher, Q. Gu, Y. Sui, P. Cao, *Chemical Engineering Journal* 2022, *435*, 133873.

[6] X. Guo, Y. Lv, L. Wang, H. Liu, W. Wang, *Optical Materials* 2024, *157*, 116097.

[7] N. Lai, D. Wang, J. Wang, L. Tang, *Energies* 2022, *15*, 8712.

[8] Y. Chen, Z. Li, Y. Li, T. Seto, Y. Wang, *Journal of Alloys and Compounds* 2021, *864*, 158103.

[9] A. M. Srivastava, W. W. Beers, M. G. Brik, A. Suchocki, D. Włodarczyk, C.-G. Ma, M. S. Kurboniyon, W. E. Cohen, *Optical Materials* 2025, *161*, 116797.

[10] T. Senden, R. J. A. Van Dijk-Moes, A. Meijerink, *Light Sci Appl* 2018, *7*, 8.

[11] W. Zhang, Y. Zhou, C. Shi, J. Ren, L. Zhang, H. Ji, *Journal of Materials Chemistry C* 2025, *13*, 2337.

[12] Q. Liu, J. Guo, M. Fan, Q. Zhang, S. Liu, K.-L. Wong, Z. Liu, B. Wei, *Journal of Materials Chemistry C* 2020, *8*, 2117.

[13] L. Zhao, D. Meng, Y. Li, Y. Zhang, H. Wang, *Journal of Alloys and Compounds* 2017, *728*, 564.

[14] L. Li, M. Dou, Y. Yan, Y. Li, F. Ling, S. Jiang, G. Xiang, J. Liu, X. Zhou, *Optical Materials* 2020, *102*, 109808.

[15] H. Patnam, Sk. K. Hussain, L. K. Bharat, J. S. Yu, *Journal of Alloys and Compounds* 2019, *780*, 846.

[16] X. Zhang, H. Song, R. Cui, M. Zhang, C. Deng, *Journal of Rare Earths* 2025, S1002072125002674.

[17] D. Wu, J. Si, J. Tang, G. Li, G. Cai, *Journal of Luminescence* 2022, *252*, 119291.