Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C.

Supplementary Information

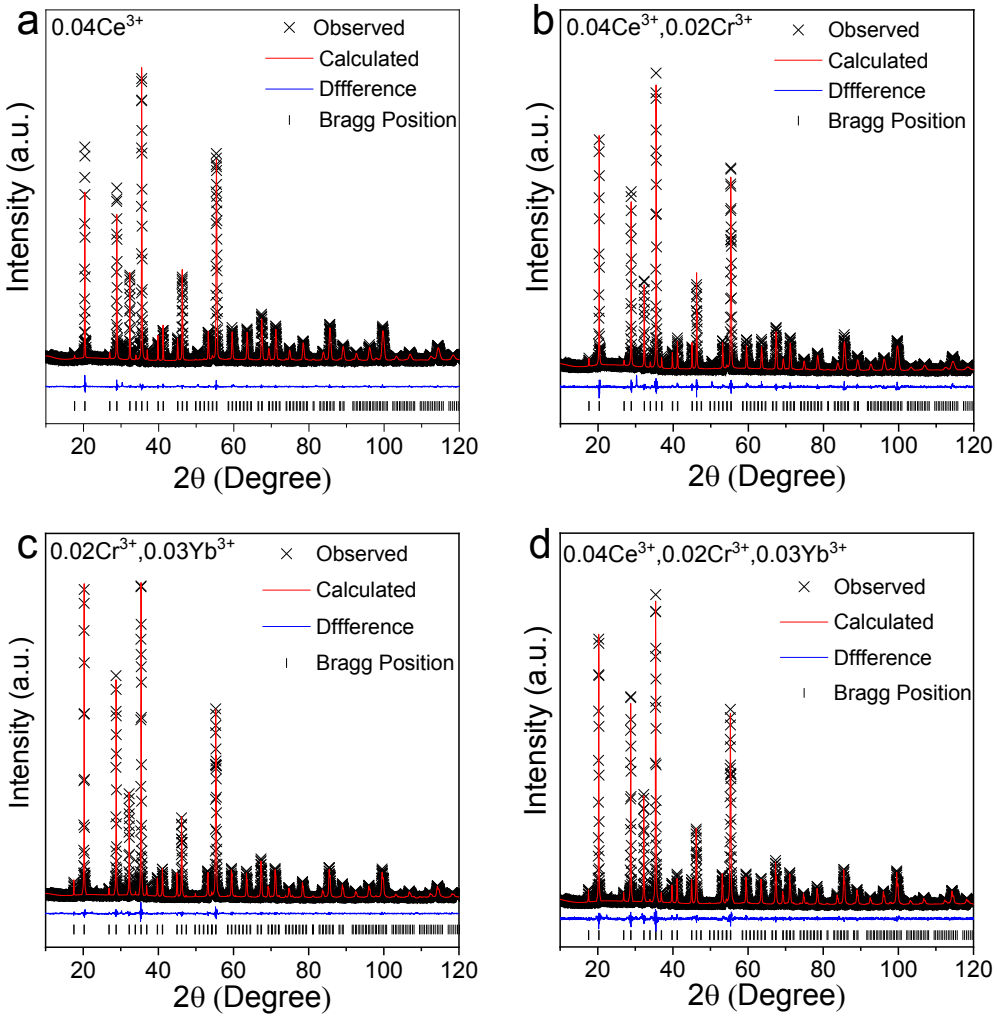

Figure S1. XRD refinements of (a) CYHA:0.04Ce^{3+}, (b) CYHA:0.04Ce^{3+},0.02Cr^{3+}, (c) CYHA:0.02Cr^{3+},0.03Yb^{3+}, and (d) CYHA:0.04Ce^{3+},0.02Cr^{3+},0.03Yb^{3+}.

Table S1. Crystallographic parameters gained from Rietveld refinements for representative CYHA, CYHA:0.04Ce^{3+}, CYHA:0.02Cr^{3+}, CYHA:0.04Ce^{3+},0.02Cr^{3+}, CYHA:0.02Cr^{3+},0.03Yb^{3+}, and CYHA:0.04Ce^{3+},0.02Cr^{3+},0.03Yb^{3+} samples.

	CYHA	**Ce^{3+}**	**Cr^{3+}**	**Ce^{3+},Cr^{3+}**	**Cr^{3+}, Yb^{3+}**	**Ce^{3+},Cr^{3+},Yb^{3+}**
Crystal system	Tetragonal (*Ia-3d*)					
α* = *β* = *γ	90°					
***a* = b = c (Å)**	12.44854(17)	12.44837(22)	12.4468(4)	12.4443(4)	12.448429	12.4510(1)
***V* (Å^3)**	1929.10(5)	1929.02(6)	1928.31(12)	1927.11(10)	1929.05	1930.15
R_{wp} (%)	7.66	7.48	7.11	6.65	5.41	4.87
R_p (%)	5.51	5.02	5.18	4.73	3.91	3.70
χ^2	4.331	4.464	2.768	3.724	3.556	2.060

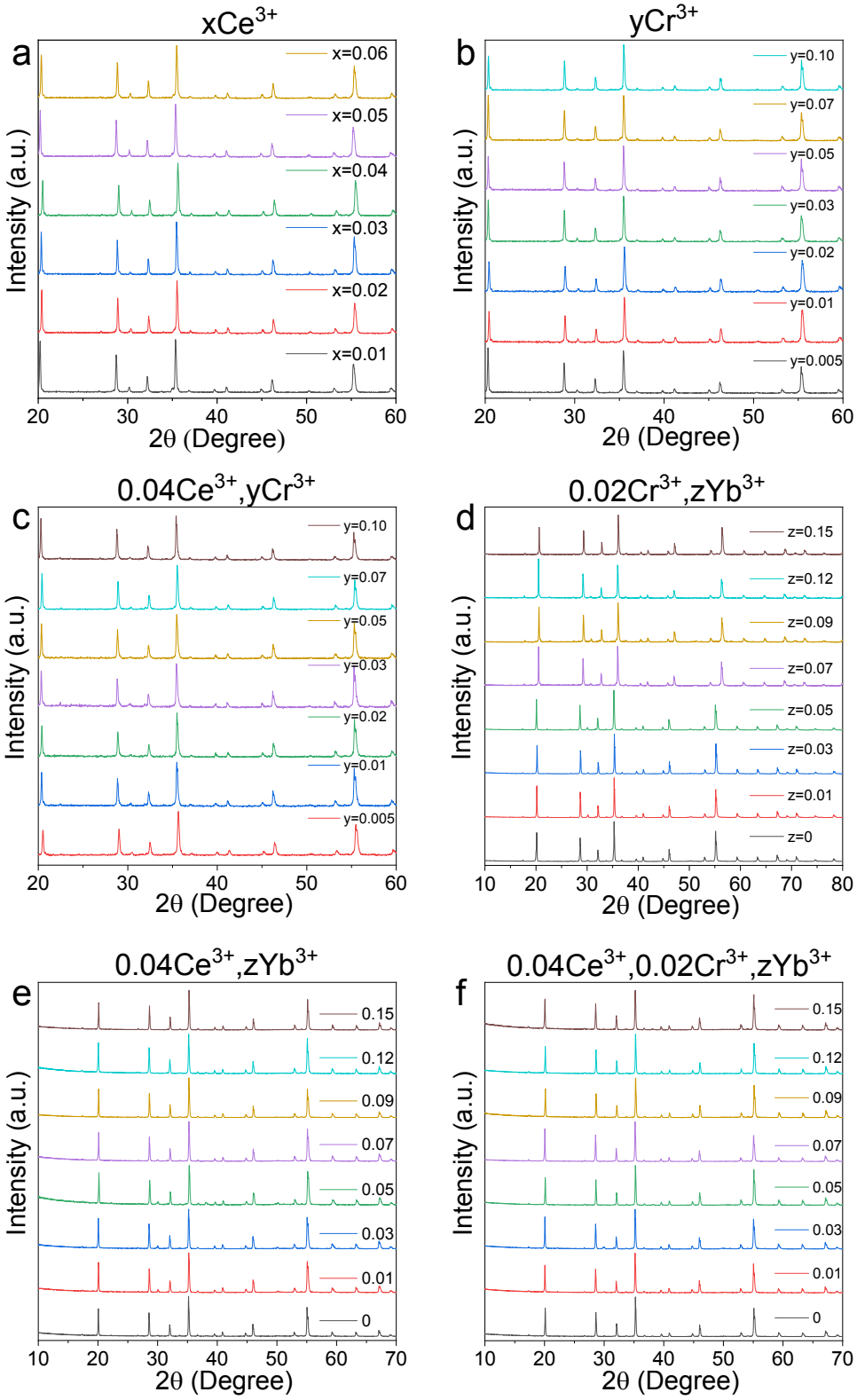

Figure S2. XRD patterns of (a) CYHA:xCe^{3+} ($0 \le x \le 0.06$), (b) CYHA:yCr^{3+} ($0.005 \le y \le 0.10$), (c) CYHA:0.04Ce^{3+},yCr^{3+} ($0.005 \le y \le 0.10$), (d) CYHA:0.02Cr^{3+},zYb^{3+} ($0 \le z \le 0.15$), (e) CYHA:0.04Ce^{3+},zYb^{3+} ($0 \le z \le 0.15$), and (f) CYHA: 0.04Ce^{3+},0.02Cr^{3+},zYb^{3+} ($0 \le z \le 0.15$)

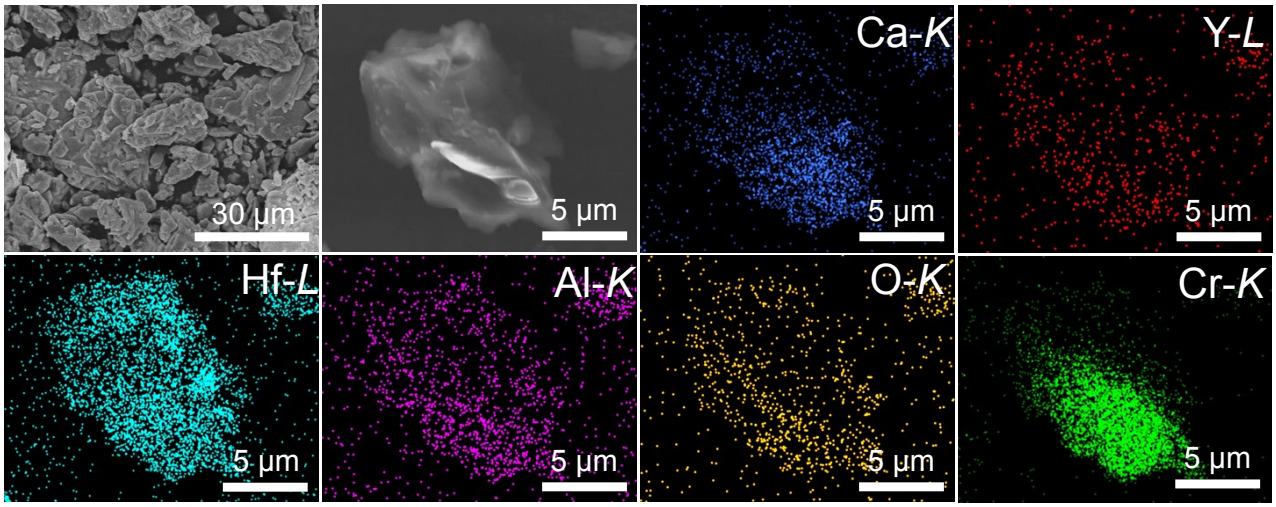

Figure S3. SEM and EDS mapping images of CYHA:0.02Cr^{3+}. All the elements show uniform distribution.

Table S2. Comparison of *D*q/B and PL properties for typical broadband NIR emitting phosphors.

Phosphors	**λ_{em} (nm)**	**FWHM (nm)**	***D*q/B**	**IQE (%)**	**I (T = 150 °C)**	**Ref.**
$Y_2CaAl_4SiO_{12}:0.06Cr^{3+}$	744	160	2.43	75.9	~80%	1
$Ca_3Sc_2Si_3O_{12}:0.06Cr^{3+}$	770	110	2.74	92.3	97.4%	2
$Ca_2YHf_2Al_3O_{12}:0.02Cr^{3+}$	775	137	2.27	75	80%	This work
$Ca_2LuScGa_2Ge_2O_{12}:0.02Cr^{3+}$	800	150	1.97	-	59%	3
$ScBO_3:0.02Cr^{3+}$	800	120	2.15	65	~51%	4
$La_2MgZrO_6:0.02Cr^{3+}$	825	210	2.53	58	<53%	5
$MgTa_2O_6:0.21Cr^{3+}$	834	140	2.50	-	-	6
$LiInSi_2O_6:0.06Cr^{3+}$	840	143	1.75	75	77%	7
$LiScP_2O_7:0.06Cr^{3+}$	880	170	1.84	38	~20%	8

Table S3. Photoelectric properties of the pc-LEDs with CYHA phosphors

	Input electrical power (mW)	400-1100 nm optical power (mW)	400-1100 nm photoelectric efficiency (%)	650-1100 nm optical power (mW)	650-1100 nm photoelectric efficiency (%)
460 nm Chip $0.02Cr^{3+}$	52.1 (20 mA)	3.856	7.40	2.71	5.20
460 nm Chip $0.02Cr^{3+},0.03Yb^{3+}$	52.06 (20 mA)	-	-	3.18	6.1
405 nm Chip $0.04Ce^{3+},0.02Cr^{3+},0.03Yb^{3+}$	58.92 (20 mA)	1.841	3.12	1.65	2.79

References

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