

Supporting Information

Achieving a tunable and ultra-broadband near-infrared emission in the $\text{Ga}_{2-2x}\text{Zn}_x\text{Ge}_x\text{O}_3$: Cr^{3+} phosphor

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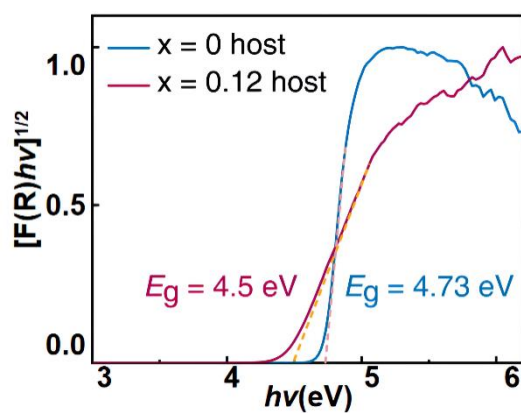


Fig. S1. The optical band gap (E_g) of Ga_2O_3 and $\text{Ga}_{1.76}\text{Zn}_{0.12}\text{Ge}_{0.12}\text{O}_3$ host.

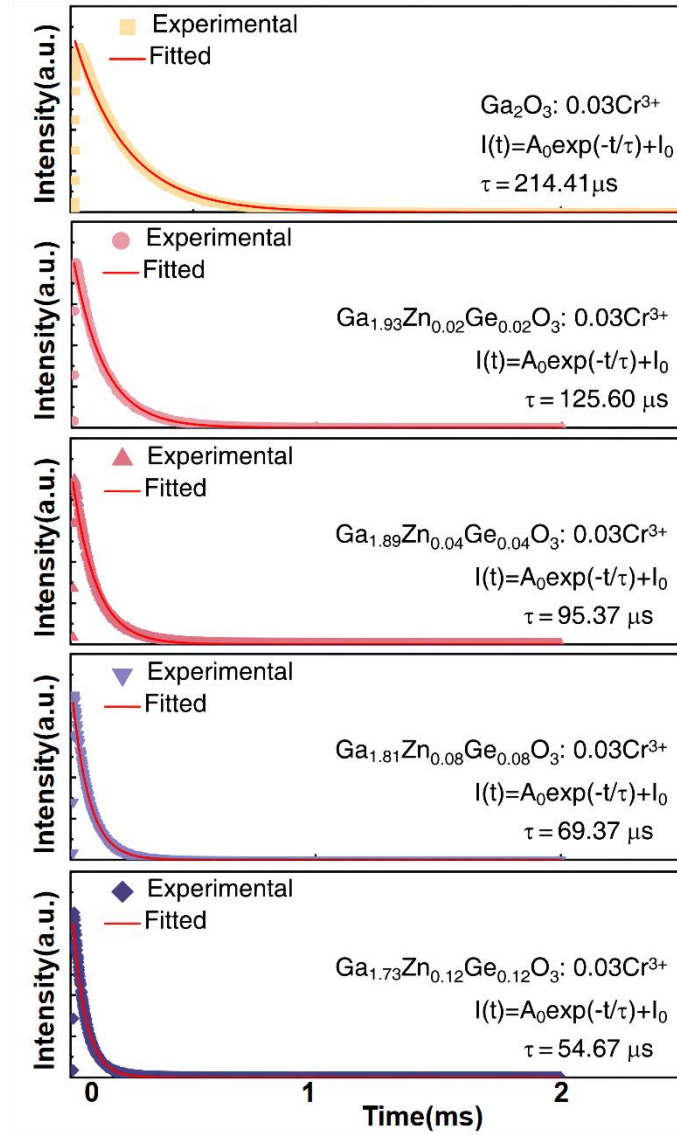


Fig. S2. Single-exponential fitting decay curve of $\text{Ga}_{1.97-2x}\text{Zn}_x\text{Ge}_x\text{O}_3: 0.03\text{Cr}^{3+}$ ($x = 0-0.12$).

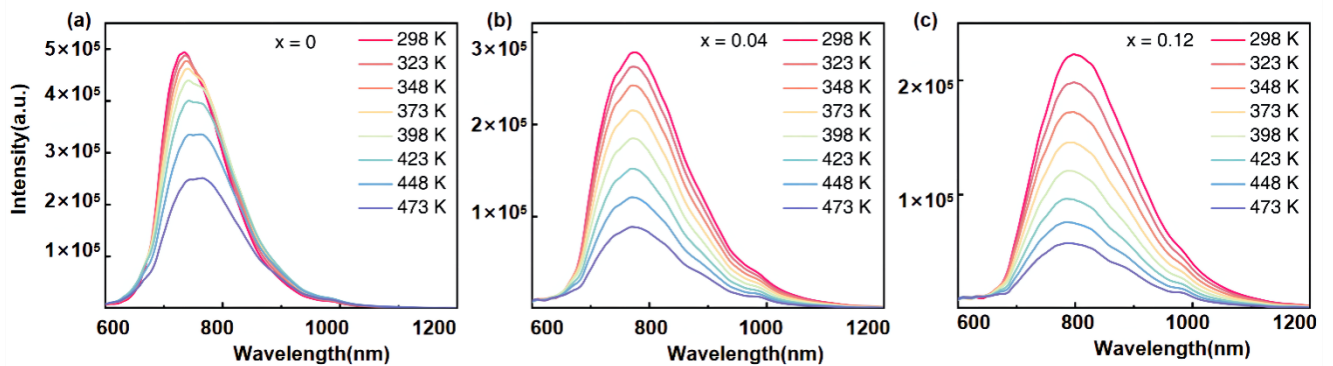


Fig. S3. Temperature-dependent PL spectra of $\text{Ga}_{1.97-2x}\text{Zn}_x\text{Ge}_x\text{O}_3: 0.03\text{Cr}^{3+}$ ($x = 0, 0.04, \text{ and } 0.12$).

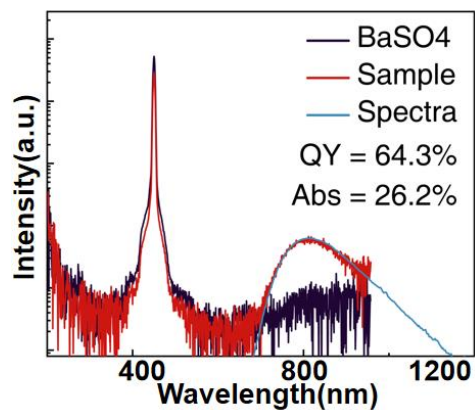


Fig. S4. The PLQY and absorption efficiency of $\text{Sc}_{0.98}\text{BO}_3: 0.02\text{Cr}^{3+}$.

Table S1. The refined atomic positions and site occupation of $\text{Ga}_2\text{O}_3: 0.03\text{Cr}^{3+}$ and $\text{Ga}_{1.73}\text{Zn}_{0.12}\text{Ge}_{0.12}\text{O}_3: 0.03\text{Cr}^{3+}$.

formula	$\text{Ga}_{1.97}\text{O}_3: 0.03\text{Cr}^{3+}$				$\text{Ga}_{1.73}\text{Zn}_{0.12}\text{Ge}_{0.12}\text{O}_3: 0.03\text{Cr}^{3+}$				
atom	occ.	<i>x</i>	<i>y</i>	<i>z</i>	atom	occ.	<i>x</i>	<i>y</i>	<i>z</i>
Ga(1)	1	0.0893(3)	0	0.2941(9)	Ga(1)	0.88	0.0906(7)	0	0.2921(8)
O(1)	1	0.1568(1)	0	0.6007(9)	O(1)	1	0.1650(5)	0	0.6133(9)
O(2)	1	0.1698(8)	0	0.0674(0)	O(2)	1	0.1716(3)	0	0.0700(7)
Ga(2)	0.97	0.3415(7)	0	0.1876(9)	Ga(2)	0.85	0.3411(9)	0	0.1854(7)
O(3)	1	0.4992(5)	0	0.2426(0)	O(3)	1	0.5077(0)	0	0.2431(2)
Cr	0.03	0.6520(4)	0	0.2514(6)	Cr	0.03	0.3413(9)	0	0.1864(2)
					Zn	0.12	0.1474(1)	0	-0.1387(1)
					Ge	0.12	0.1169(0)	0	0.4151(7)

Table S2. The refined crystal structure of $\text{Ga}_{1.97}\text{O}_3: 0.03\text{Cr}^{3+}$, and $\text{Ga}_{1.73}\text{Zn}_{0.12}\text{Ge}_{0.12}\text{O}_3: 0.03\text{Cr}^{3+}$ with Zn^{2+} and Ge^{4+} occupying different Ga^{3+} sites.

formula	$\text{Ga}_{1.97}\text{O}_3: 0.03\text{Cr}^{3+}$	$\text{Ga}_{1.73}\text{Zn}_{0.12}\text{Ge}_{0.12}\text{O}_3: 0.03\text{Cr}^{3+}$			
		$[\text{Ga}/\text{Zn}]\text{O}_6$	$[\text{Ga}/\text{Ge}]\text{O}_6$	$[\text{Ga}]\text{O}_6$	$[\text{Ga}/\text{Zn}/\text{Ge}]\text{O}_6$
		$[\text{Ga}/\text{Ge}]\text{O}_4$	$[\text{Ga}/\text{Zn}]\text{O}_4$	$[\text{Ga}/\text{Zn}/\text{Ge}]\text{O}_4$	$[\text{Ga}]\text{O}_4$
radiation type; λ (Å)	X-ray; 1.5406	X-ray; 1.5406	X-ray; 1.5406	X-ray; 1.5406	X-ray; 1.5406
2θ range (°)	5-120	5-120	5-120	5-120	5-120
temperature (°C)	25	25	25	25	25
space group; Z	$C2/m;2$	$C2/m;2$	$C2/m;2$	$C2/m;2$	$C2/m;2$
a (Å)	12.2300(6)	12.2626(8)	12.2626(9)	12.2626(7)	12.2629(3)
b (Å)	3.0410(2)	3.0440(0)	3.0439(8)	3.0439(8)	3.0440(4)
c (Å)	5.8099(0)	5.8071(0)	5.8070(3)	5.8070(2)	5.8072(0)
β (°)	103.82(7)	103.71(3)	103.71(6)	103.71(6)	103.71(6)
unit cell volume (Å ³)	216.07(8)	216.76(3)	216.75(3)	216.75(3)	216.77(3)
R_p	0.0350	0.0335	0.0557	0.0555	0.0757
R_{wp}	0.0551	0.0736	0.0836	0.0834	0.1051
χ^2	4.95	8.65	11.15	11.10	17.59