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Synthesis of color-tunable Cu–In–Ga–S solid solution quantum dots with high quantum yields for application to white light-emitting diodes

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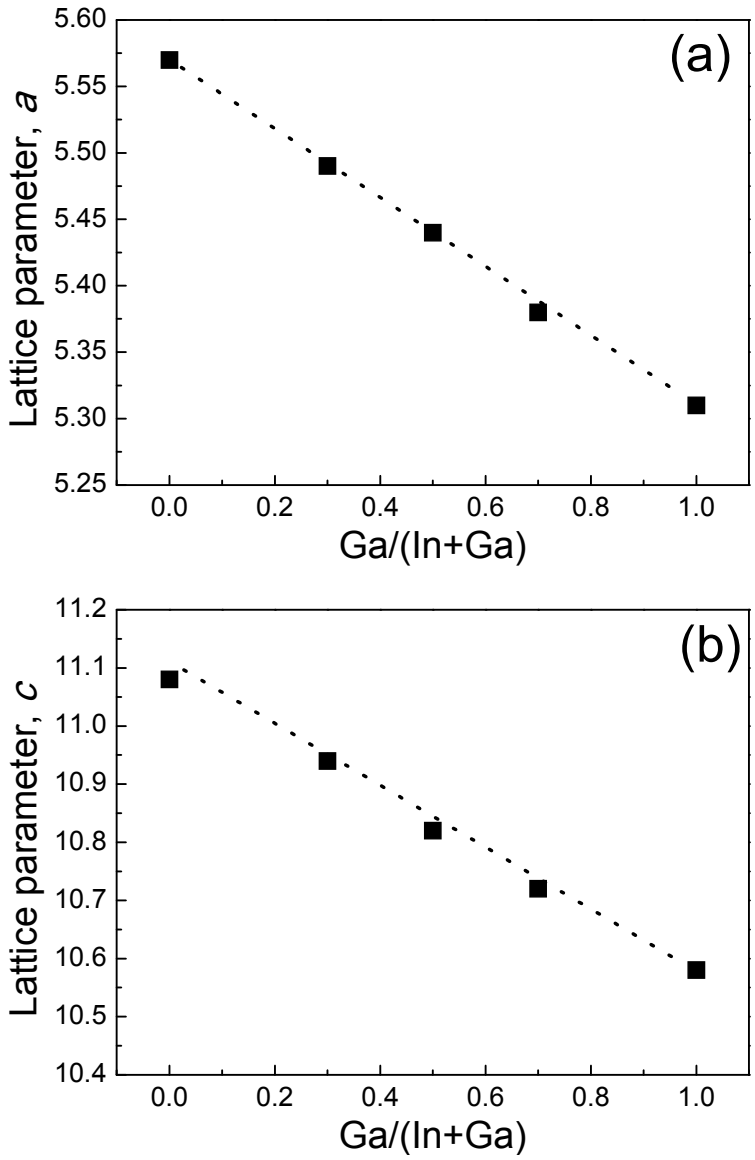

Fig. S1. Plots of lattice parameters (a) *a* and (b) *c* of CIGS QDs as a function of In:Ga ratio.

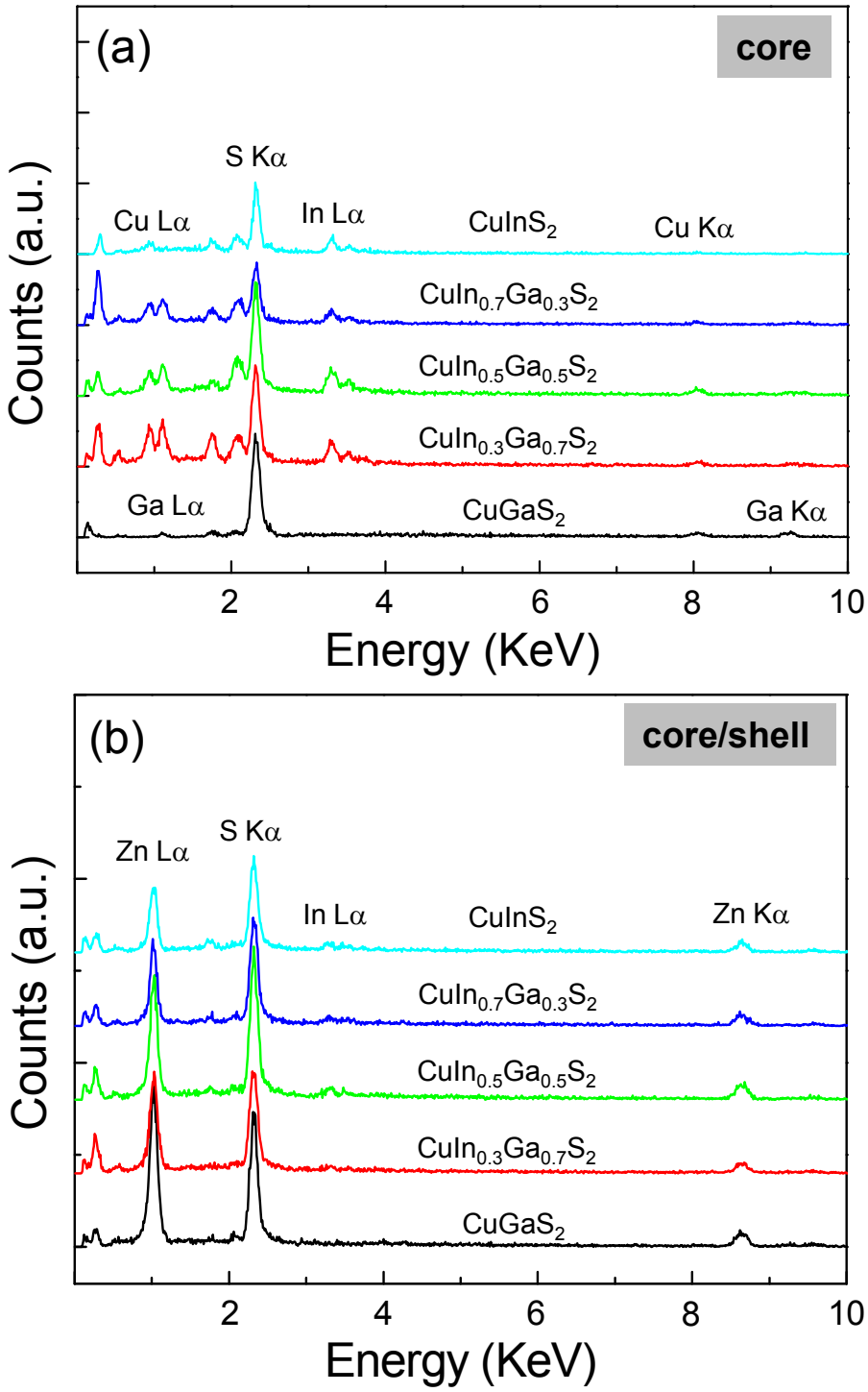

Fig. S2. EDS spectra of (a) CIGS and (b) CIGS/ZnS QDs having various In:Ga ratios.

Table S1. EDS-based chemical compositions of CIGS and CIGS/ZnS QDs having various In:Ga ratios.

Element	In:Ga (at %) in CIGS core QDs				
	0:1.0	**0.3:0.7**	**0.5:0.5**	**0.7:1.0**	**1.0:0**
Cu	7.60	7.77	7.72	7.76	7.39
In	-	10.19	15.57	20.91	29.07
Ga	30.13	22.79	15.08	9.40	-
Element	**In:Ga (at %) in CIGS/ZnS core/shell QDs**				
	0:1.0	**0.3:0.7**	**0.5:0.5**	**0.7:1.0**	**1.0:0**
Cu	1.48	1.45	1.55	1.40	1.21
In	-	1.88	3.50	3.85	4.98
Ga	5.83	4.12	3.35	1.61	-
Zn	39.77	41.10	45.05	38.48	34.12

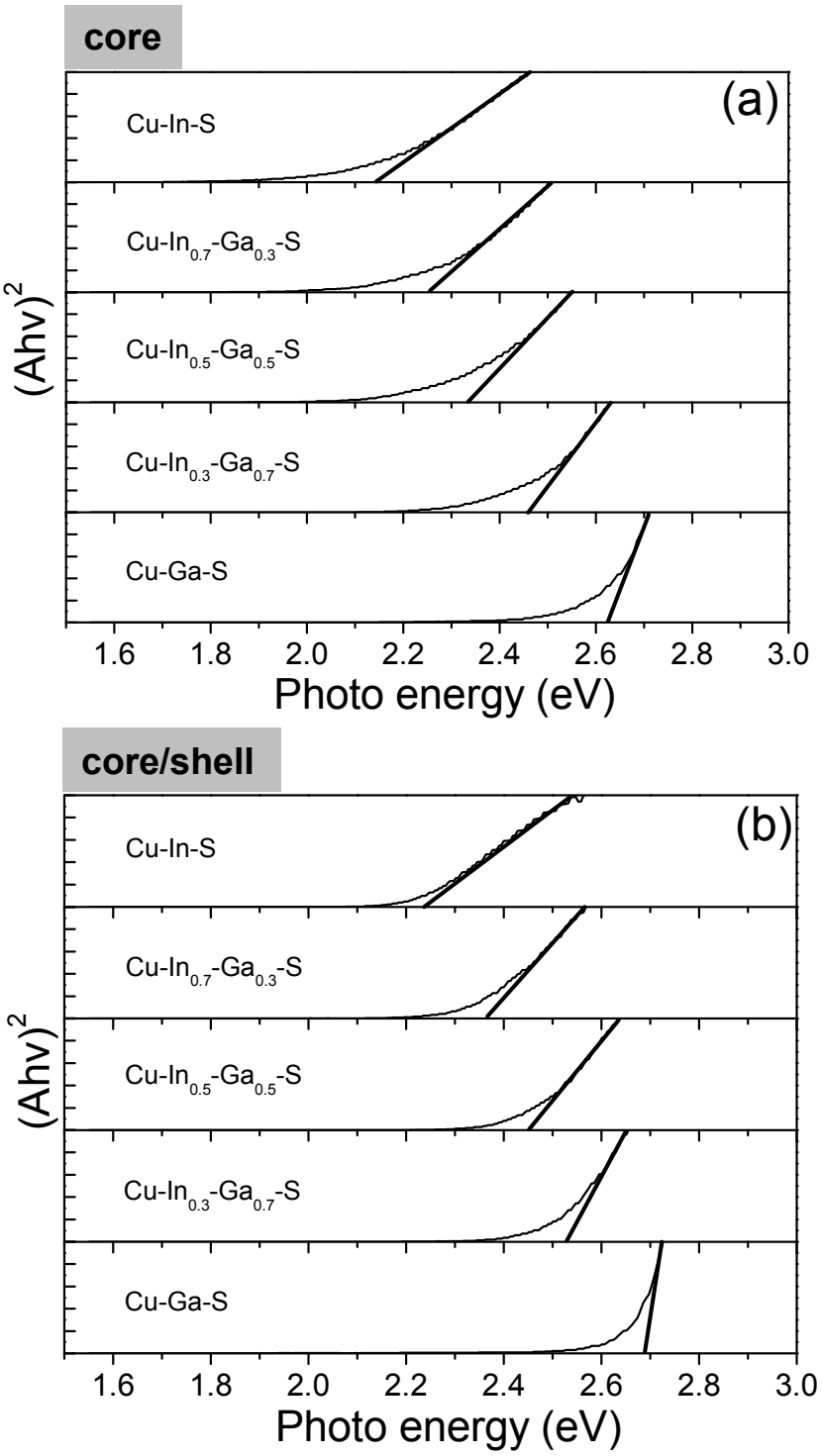

Fig. S3. Converted plots of $(Ah\nu)^2$ versus $h\nu$ of (a) CIGS and (b) CIGS/ZnS QDs from the absorption spectra of Figure 3(a,b), respectively, for determining the band gap by extrapolating the straight part of the graph to energy $h\nu$ axis.

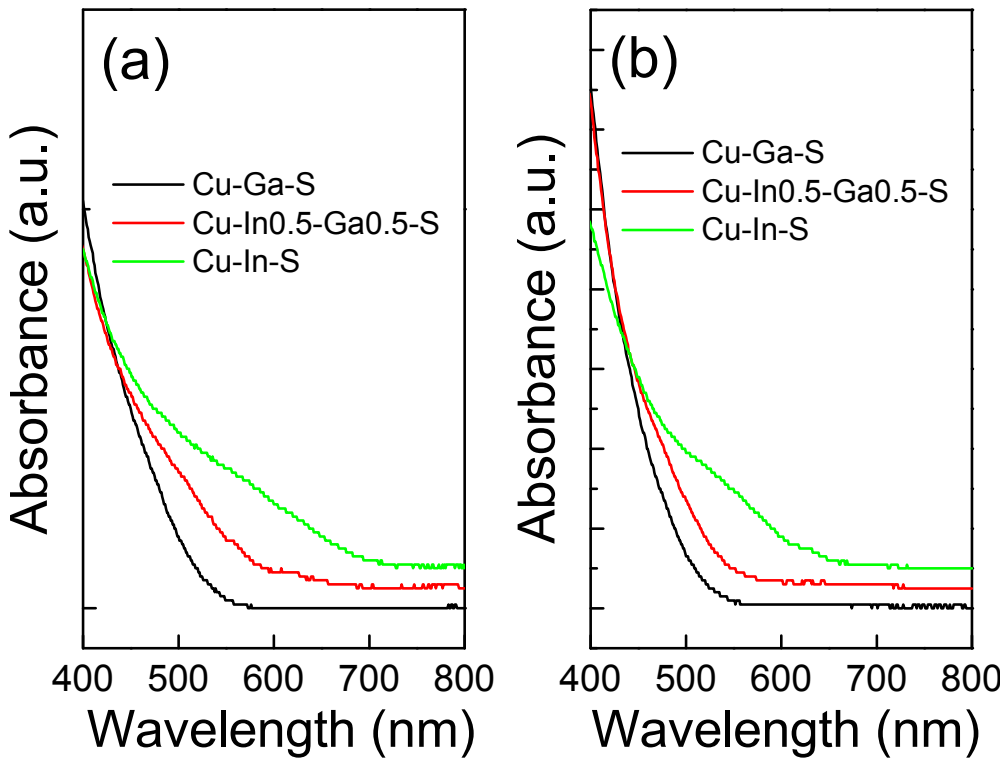

Fig. S4. UV-visible absorption spectra of (a) CIS, $CI_{0.5}G_{0.5}S$, CGS and (b) the respective core/shell QDs with a stoichiometric Cu:(In+Ga) precursor ratio of 1:1.

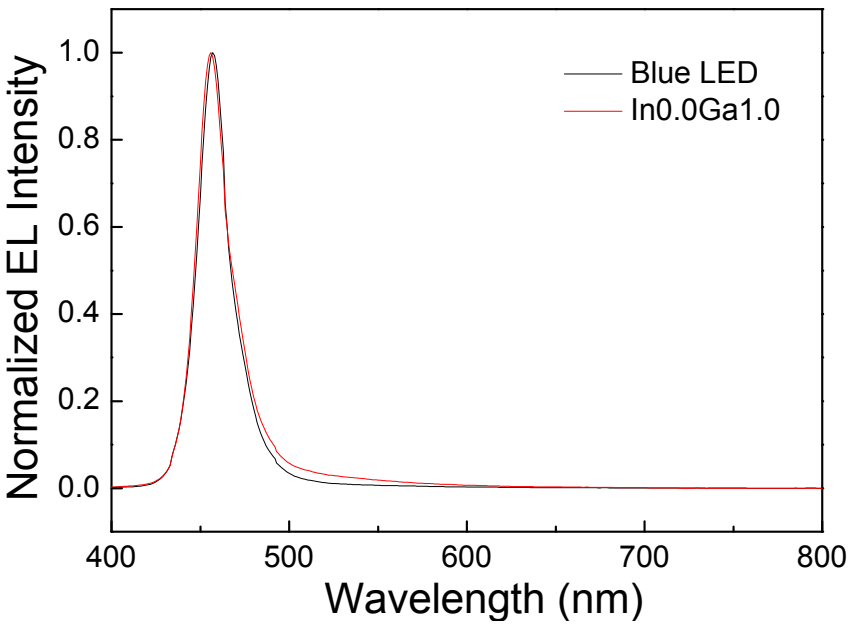

Fig. S5. Comparison of EL spectra of CGS/ZnS QD-based LED versus bare blue LED at a forward current of 20 mA.

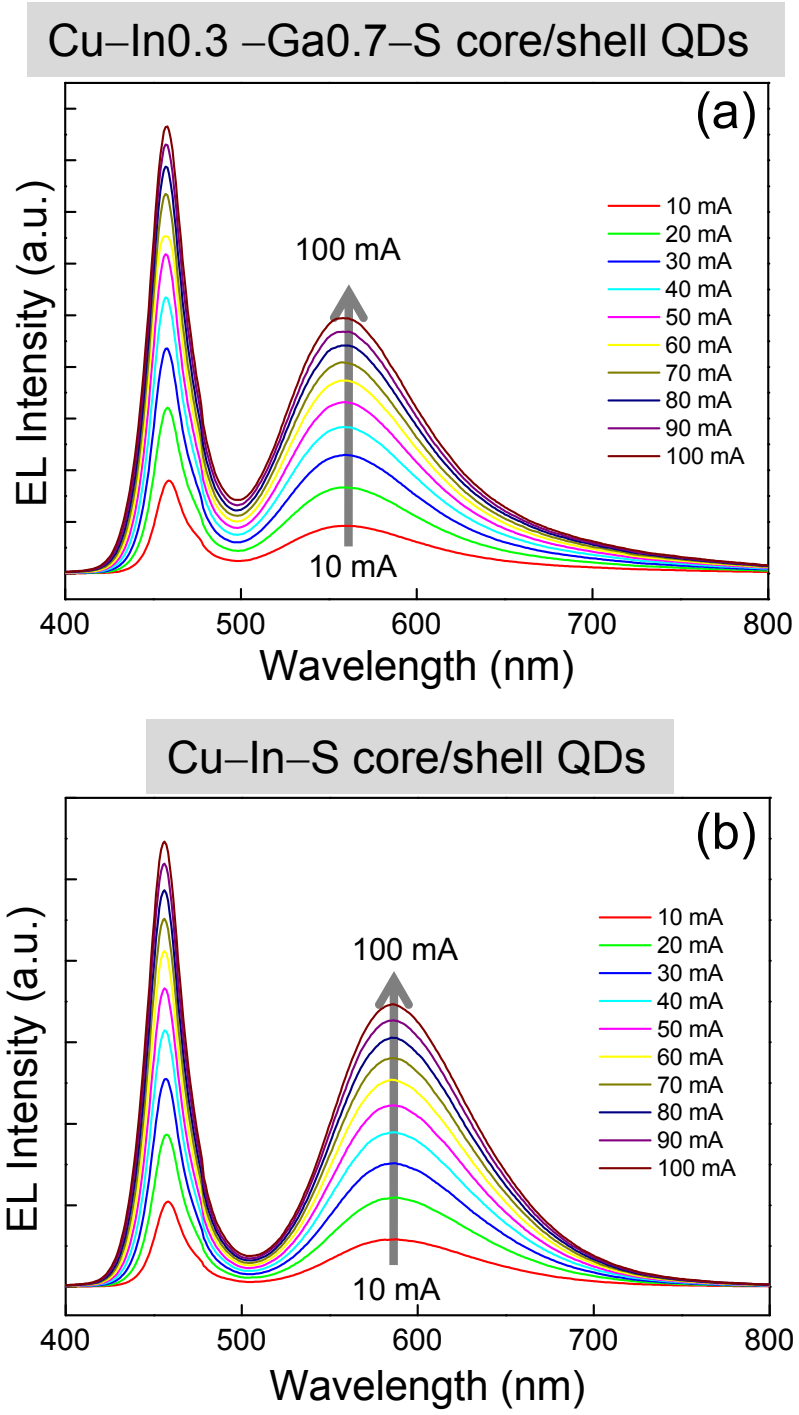

Fig. S6. EL spectra of white QD-LEDs combined with (a) Cu–In0.3–Ga0.7–S/ZnS and (b) Cu–In–S/ZnS QDs as a function of forward current.

Table S2. Variations of luminous efficacy, conversion efficiency, CRI, and CCT of white QD-LEDs in Figure S5 as a function of forward current.

Cu–In0.3 –Ga0.7–S core/shell QDs					
Forward Current (mA)	**Luminous Efficacy (lm/W)**	**Conversion Efficiency (%)**	**CRI**	**CCT (K)**	**CIE Color Coordinates**
10	81.0	76	71	6857	(0.307,0.324)
20	69.1	74	72	7048	(0.305,0.320)
30	60.5	72	72	7198	(0.303,0.317)
40	53.9	70	72	7363	(0.302,0.314)
50	48.6	69	72	7472	(0.301,0.312)
60	44.2	67	72	7472	(0.300,0.312)
70	40.2	66	72	7527	(0.299,0.312)
80	37.0	65	72	7582	(0.299,0.311)
90	34.1	64	72	7692	(0.298,0.310)
100	31.6	64	72	7692	(0.298,0.309)
Cu–In–S core/shell QDs					
Forward Current (mA)	**Luminous Efficacy (lm/W)**	**Conversion Efficiency (%)**	**CRI**	**CCT (K)**	**CIE Color Coordinates**
10	85.4	96	71	3923	(0.358,0.288)
20	75.0	96	71	3892	(0.359,0.288)
30	66.4	94	71	3938	(0.357,0.286)
40	60.0	93	71	3954	(0.356,0.285)
50	54.5	92	72	4033	(0.355,0.283)
60	50.0	91	72	4050	(0.354,0.282)
70	46.1	90	72	4067	(0.353,0.281)
80	42.6	90	72	4084	(0.353,0.280)
90	39.6	89	73	4117	(0.352,0.279)
100	36.8	88	73	4134	(0.351,0.279)