Supplementary Information

Ga Back-Graded $CuInSe_2$ Thin Films for High-Performance Near-Infrared Photodetectors

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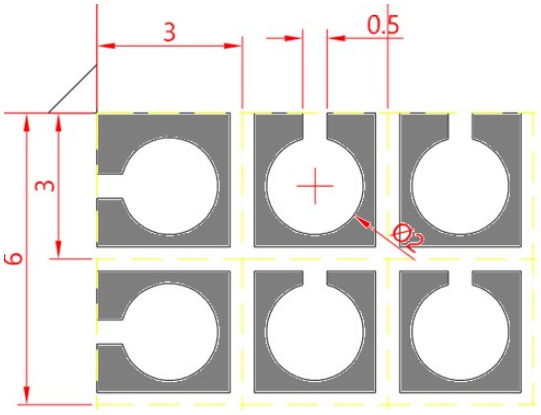

Fig. S1. Schematic layout and dimensional parameters of the Ag top electrode (dimensions in mm).

Table S1. State-of-the-art PCE values of CISe and CIGS solar cells.

Device Type	Absorber	PCE (%)	Optimization Strategy	Ref.
CIGS/SLG	Ag-alloyed CIGS	23.64	Ag alloying + RbF PDT	[1]
CIGS/UTG	Ag-alloyed CIGS on UTG	17.81	Ag alloying + NaF/RbF PDT + ZnMgO	[2]
CISe/SLG	Ag-alloyed CISe	18.70	Ag alloying + Rb–In–Se capping + NaF PDT	[3]
CISe/SLG	Pure CISe	13.20	No front passivation	[4]
CISe/SLG	Pure CISe	6.17	No front passivation; inverted 1st/3rd stages	This work

Table S2. State-of-the-art NIR photodetection performance of CISe and CIGS photodetectors.

Material	Device Structure	λ (nm)	R (AW^{-1}) at 0 V bias	D* (Jones) at 0 V bias	Response Time	Active area	Ref.
CIGS	Mo/CIGS/CdS/ZnO/ITO (SLG)	660	0.25	1.2×10^{11}	0.05 µs	N/A	[5]
CISe	ITO/HybridHTL/CISe QDs/ZnO/Ag	1050	0.08	2.1×10^{12}	0.64 ms	0.78 mm^2	[6]
CISe	ITO/PEDOT:PSS/Mn–CISe QDs/PCBM/Ag	1000	0.03	4.2×10^{12}	0.76 µs	0.10 cm^2	[7]
CISe	SLG/Mo/CISe/CdS/i-ZnO/ITO/Ag	1064	0.67	2.5×10^{12}	0.18 ms	3.14 mm^2	This work

Table S3. FESEM-EDS analysis of Ref, Ga3 and Ga6 thin films from bottom (P1) to top (P5).

	G0 (at.%)					G3 (at.%)					G6 (at.%)				
Elem.	P1	P2	P3	P4	P5	P1	P2	P3	P4	P5	P1	P2	P3	P4	P5
Cu	23.62	23.45	23.53	23.64	23.46	22.09	22.13	22.93	23.48	23.72	22.87	22.76	23.22	24.1	24.3
In	26.30	26.67	26.52	26.24	26.61	25.45	25.86	25.81	25.61	25.73	23.59	24.25	25.1	25.01	25.46
Ga	0	0	0	0	0	2.17	1.54	0.69	0.52	0.11	4.13	3.78	1.45	0.41	0.37
Se	50.08	49.88	49.95	50.12	49.93	50.29	50.47	50.57	50.39	50.44	49.41	49.21	50.23	50.48	49.87
CGI	0.898	0.879	0.887	0.9								0.812	0.875	0.948	0.941
GGI	0.000	0.000	0.000	0.0								0.135	0.055	0.016	0.014

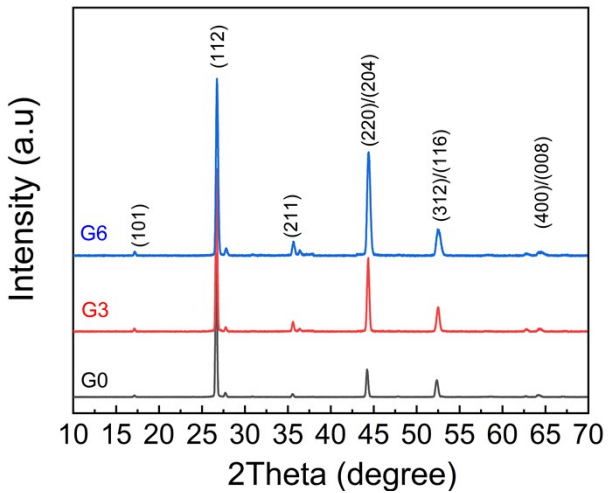

Fig. S2. XRD spectrums of CISe films G0, G3 and G6.

Table S4. XRD peak positions and FWHM analysis of (112) peak for G0, G3 and G6 thin films.

XRD peaks	**(112)**	**(220)**	**(312)**	**FWHM of (112)**
G0	26.67	44.22	52.34	0.284
G3	26.70	44.35	52.48	0.232
G6				.225

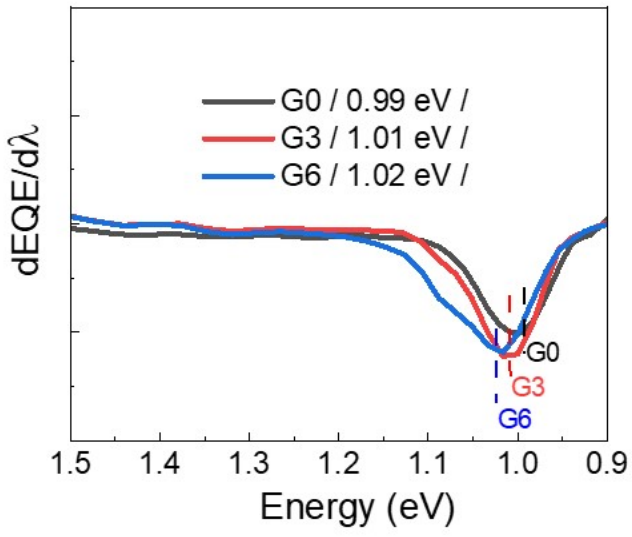

Fig. S3. Optical bandgap (E_g) extraction of G0, G3 and G6 devices.

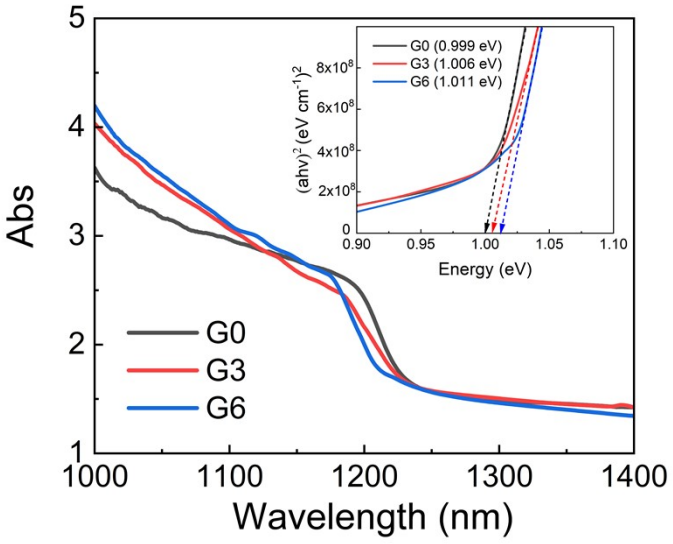

Fig. S4. NIR absorption spectra of G0, G3, and G6 thin films deposited on bare SLG substrates. The inset shows the Tauc ($(\alpha h\nu)^2$ vs. $h\nu$) analysis.

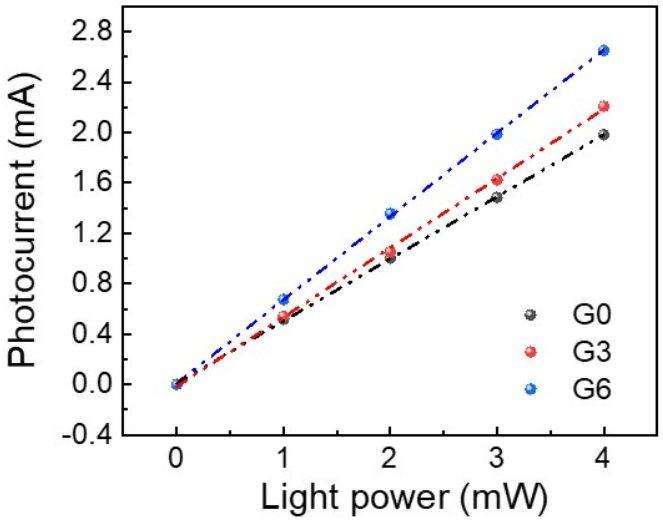

Fig. S5. Illumination light power vs. photo-current for G0, G3 and G6 devices at 0 V bias.

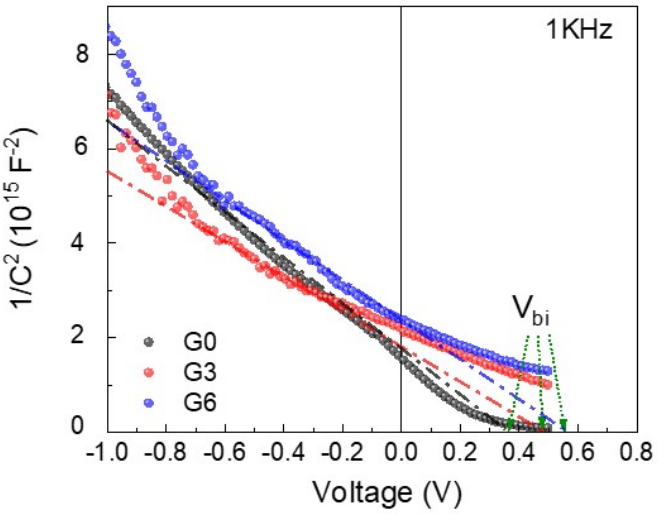

Fig. S6. Mott-Schottky plot for G0, G3 and G6 devices.

References

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