

Supplementary Information

High quality CdS buffer layer developed via Zn salt additive engineering for Sb₂S₃ solar cells

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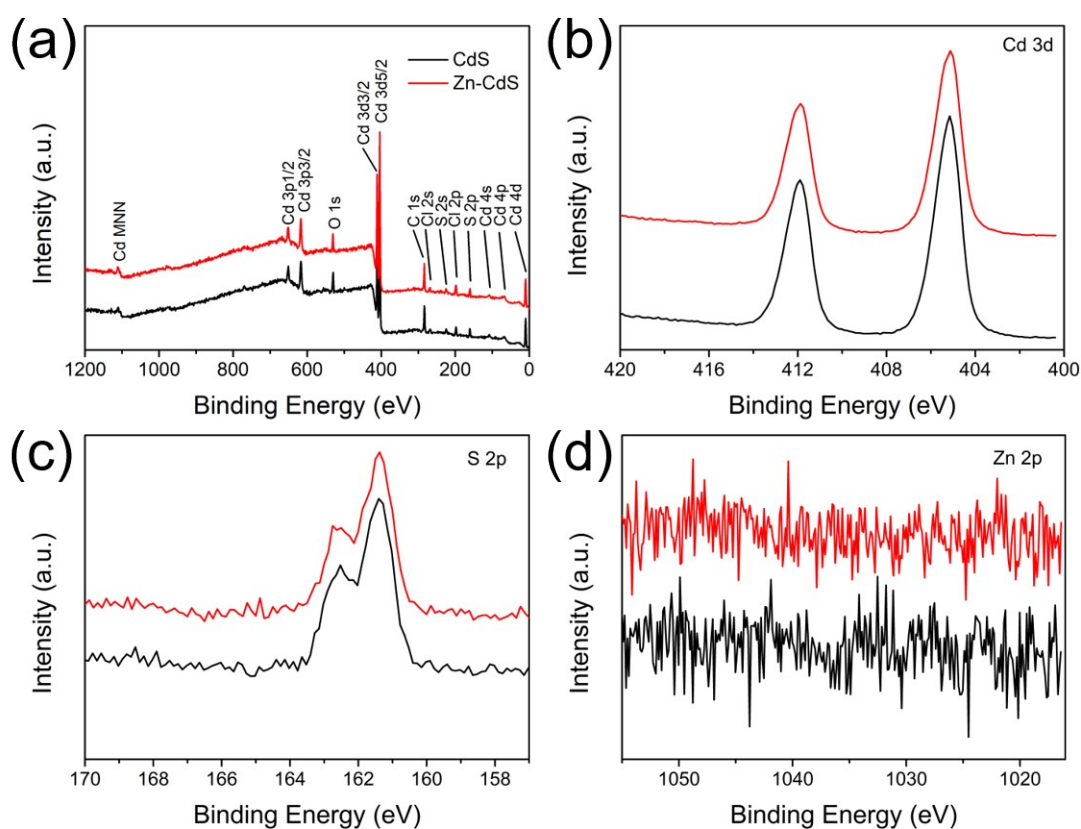


Fig. S1 (a) XPS survey, (b) Cd 3d, (c) S 2p and (d) Zn 2p spectra of the CdS and Zn-CdS thin films.

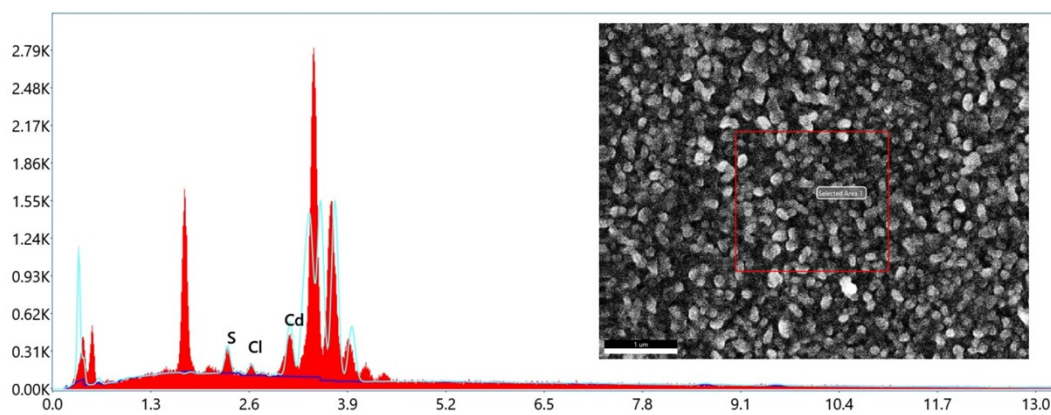


Fig. S2 Energy dispersive X-ray spectroscopy (EDS) spectrum of the Zn-CdS thin film.

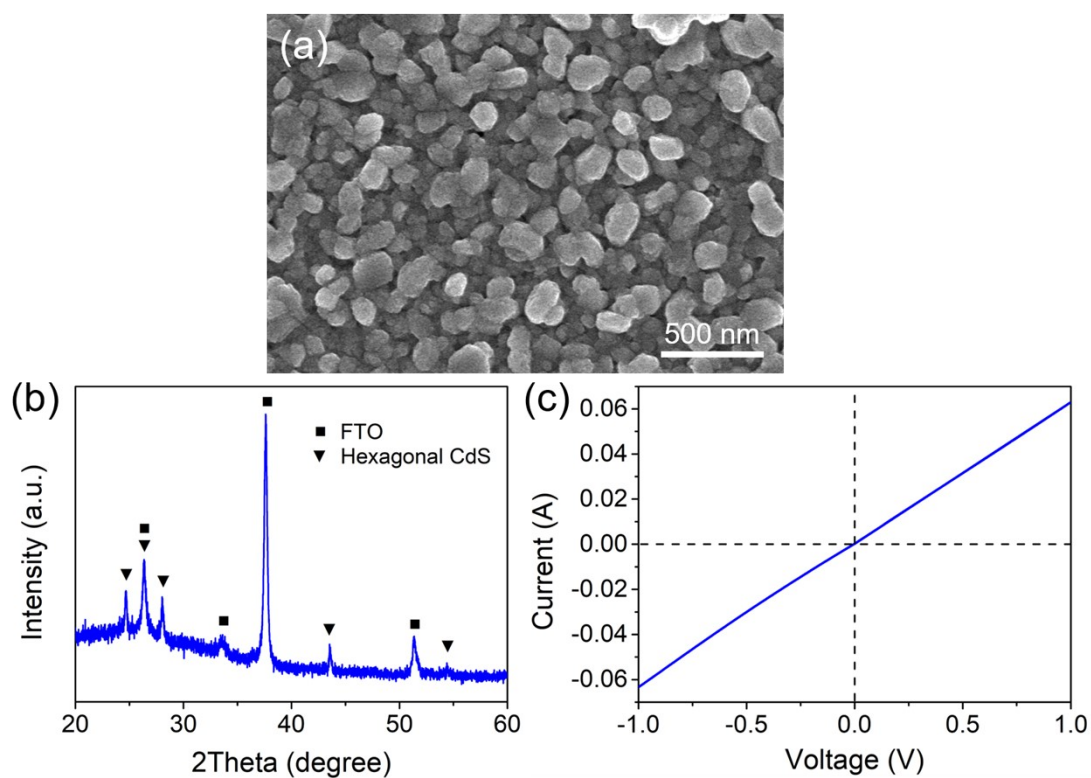


Fig. S3 (a) Top-view SEM image and (b) XRD pattern of the Zn-CdS thin film. (c) I - V curve of FTO/Zn-CdS/Ag device. The Zn-CdS buffer layer was deposited using a 20 mL mixture solution of CdSO_4 (0.015 M) and ZnSO_4 (0.0015 M), which had the same Cd concentration as the pristine CdS CBD solution.

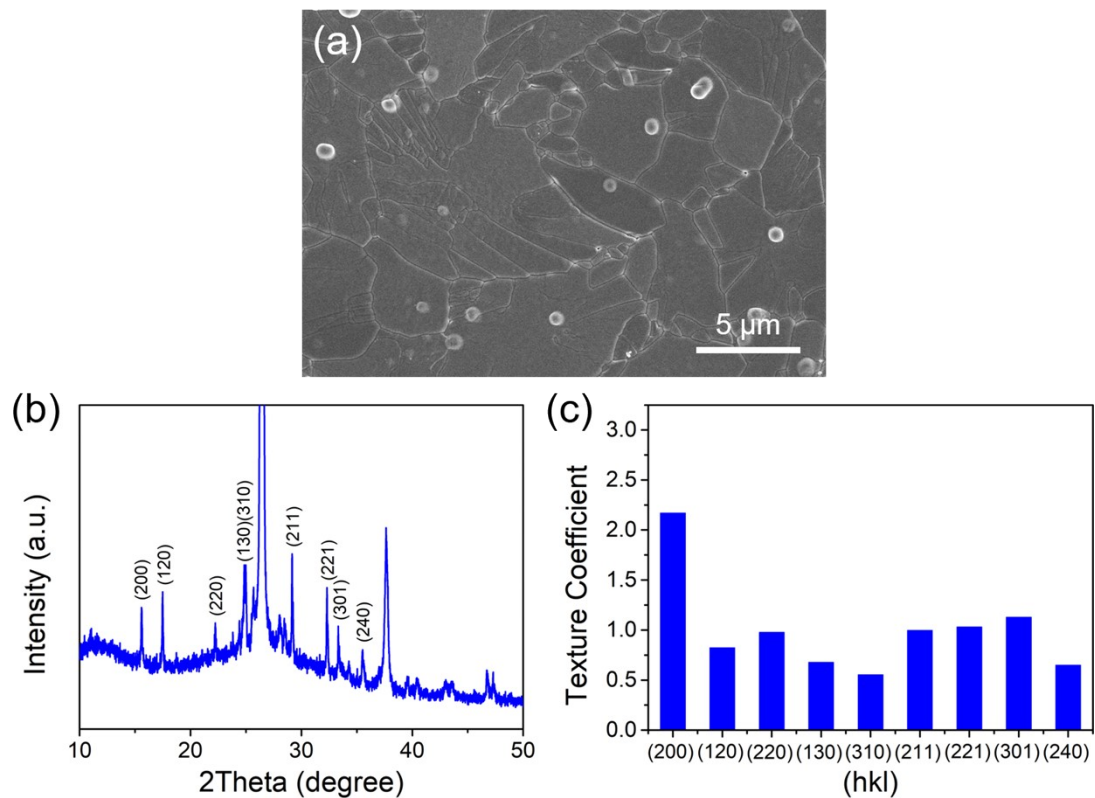


Fig. S4 (a) Top-view SEM image of Sb_2S_3 thin film deposited on the Zn-CdS substrate. (c) XRD pattern of the Sb_2S_3 solar cell based on the Zn-CdS substrate. (d) Texture coefficients of Sb_2S_3 thin film deposited on the Zn-CdS substrate. The Zn-CdS buffer layer in this device was deposited using a 20 mL mixture solution of CdSO_4 (0.015 M) and ZnSO_4 (0.0015 M), which had the same Cd concentration as the pristine CdS CBD solution.

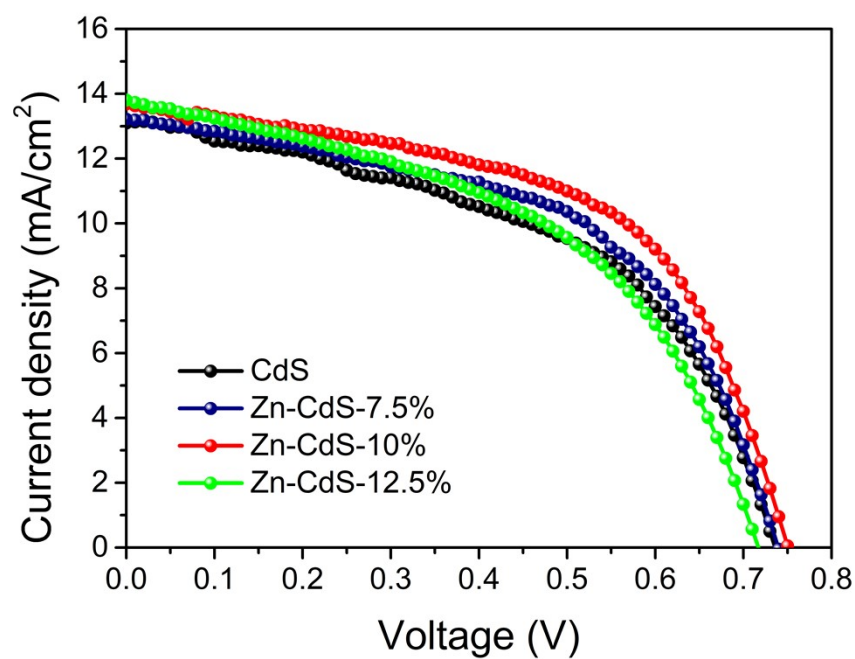


Fig. S5 Characteristic J - V curves of Sb_2S_3 thin film solar cells based on the CdS and Zn-CdS buffer layers.

Table S1 Photovoltaic parameters of the Sb_2S_3 thin film solar cells based on the CdS and Zn-CdS buffer layers.

ETL	V_{OC} (V)	J_{SC} (mA/cm ²)	FF (%)	PCE (%)
CdS	0.736	13.10	50.8	4.90
Zn-CdS-7.5%	0.739	13.21	54.2	5.29
Zn-CdS-10%	0.751	13.69	55.9	5.74
Zn-CdS-12.5%	0.717	13.80	48.3	4.78

Table S2 Photovoltaic parameters of the CdS devices and the Zn-CdS devices.

Sample	V_{OC} (V)	J_{SC} (mA/cm ²)	FF (%)	PCE (%)	Sample	V_{OC} (V)	J_{SC} (mA/cm ²)	FF (%)	PCE (%)
CdS-1	0.736	13.10	50.8	4.90	Zn-CdS-1	0.751	13.69	55.9	5.74
CdS-2	0.725	13.17	51.1	4.88	Zn-CdS-2	0.744	14.40	52.9	5.67
CdS-3	0.733	13.38	49.2	4.82	Zn-CdS-3	0.768	13.60	54.2	5.66
CdS-4	0.739	13.41	48.6	4.81	Zn-CdS-4	0.748	14.18	53.2	5.64
CdS-5	0.733	13.11	49.8	4.78	Zn-CdS-5	0.755	13.92	53.6	5.63
CdS-6	0.752	13.72	46	4.74	Zn-CdS-6	0.761	14.01	52.5	5.60
CdS-7	0.730	13.14	49.1	4.71	Zn-CdS-7	0.742	13.77	54.6	5.58
CdS-8	0.743	13.37	47.4	4.70	Zn-CdS-8	0.744	14.08	53.3	5.58
CdS-9	0.726	12.93	49.9	4.69	Zn-CdS-9	0.739	14.78	51.1	5.58
CdS-10	0.708	13.75	47.7	4.64	Zn-CdS-10	0.741	14.19	52.8	5.55
CdS-11	0.719	13.64	47.3	4.64	Zn-CdS-11	0.741	14.55	51.3	5.53
CdS-12	0.754	13.42	45.8	4.64	Zn-CdS-12	0.740	14.26	52.4	5.52
CdS-13	0.721	13.30	48.1	4.61	Zn-CdS-13	0.738	14.08	52.7	5.47
CdS-14	0.726	13.41	47.3	4.61	Zn-CdS-14	0.734	14.32	51.2	5.39
CdS-15	0.728	12.33	50.7	4.55	Zn-CdS-15	0.740	13.95	51.9	5.36
CdS-16	0.725	12.72	49.2	4.54	Zn-CdS-16	0.741	14.08	51.1	5.33
CdS-17	0.743	12.56	48.7	4.54	Zn-CdS-17	0.737	13.73	52.7	5.32
CdS-18	0.731	13.06	47.3	4.52	Zn-CdS-18	0.724	13.90	52.5	5.28
CdS-19	0.727	13.28	46.8	4.52	Zn-CdS-19	0.737	14.19	50.5	5.28
CdS-20	0.727	12.59	49.2	4.50	Zn-CdS-20	0.734	13.62	52.3	5.22
CdS-21	0.723	12.33	50.4	4.50	Zn-CdS-21	0.743	13.44	52.1	5.20
CdS-22	0.723	12.86	48.4	4.50	Zn-CdS-22	0.742	14.02	50.0	5.20
CdS-23	0.719	12.74	48.9	4.48	Zn-CdS-23	0.737	13.88	50.0	5.12
CdS-24	0.724	12.78	48.4	4.48	Zn-CdS-24	0.737	13.81	49.8	5.08
CdS-25	0.721	13.07	47.4	4.47	Zn-CdS-25	0.733	14.13	49.0	5.08
CdS-26	0.731	12.60	48.1	4.43	Zn-CdS-26	0.730	14.39	48.4	5.08
CdS-27	0.724	13.30	46.0	4.43	Zn-CdS-27	0.734	14.11	49.0	5.07
CdS-28	0.713	13.44	46.0	4.40	Zn-CdS-28	0.741	13.98	48.8	5.05
CdS-29	0.716	13.36	45.7	4.37	Zn-CdS-29	0.727	13.86	49.6	4.98
CdS-30	0.746	12.49	46.5	4.33	Zn-CdS-30	0.724	13.73	49.9	4.96
CdS-31	0.732	13.04	44.9	4.28	Zn-CdS-31	0.731	14.07	46.2	4.75
CdS-32	0.738	12.82	44.7	4.24	Zn-CdS-32	0.726	13.56	48.0	4.73

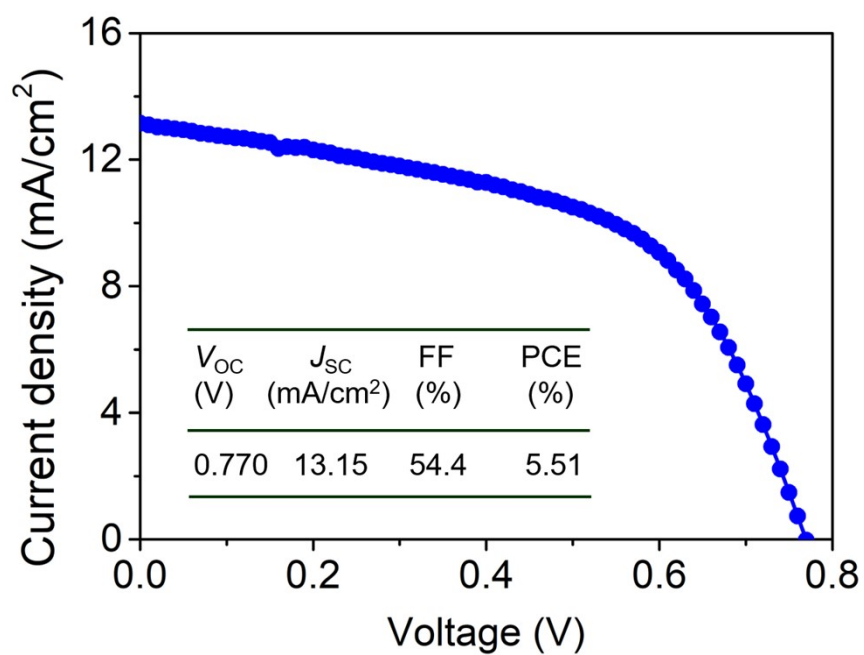


Fig. S6 Characteristic J - V curve of Sb_2S_3 thin film solar cell. The Zn-CdS buffer layer in this device was deposited using a 20 mL mixture solution of $CdSO_4$ (0.015 M) and $ZnSO_4$ (0.0015 M), which had the same Cd concentration as the pristine CdS CBD solution.

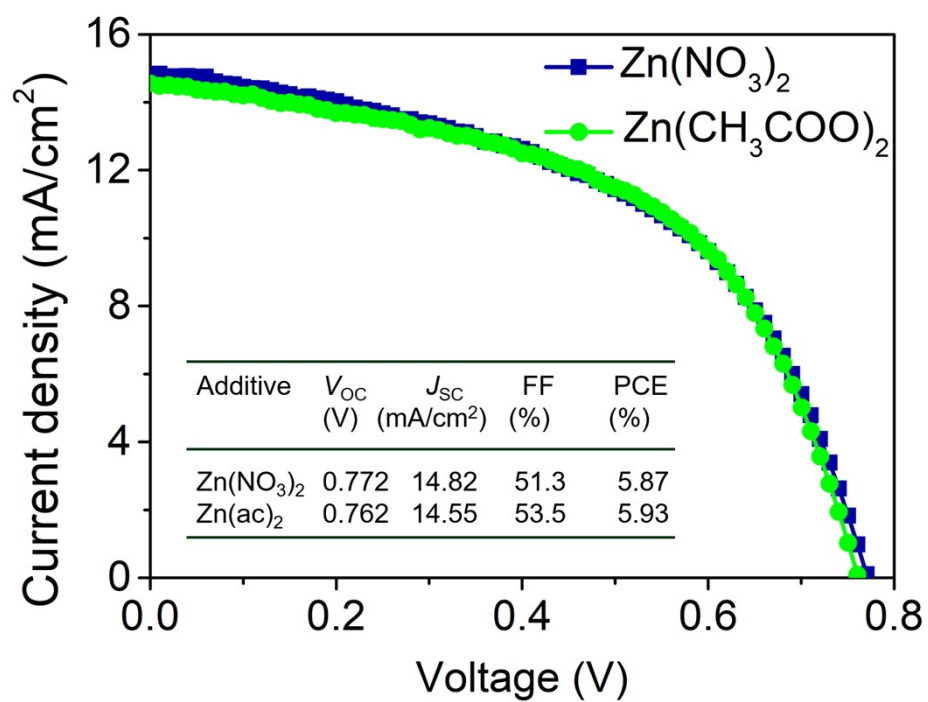


Fig. S7 Characteristic J - V curves of Sb₂S₃ thin film solar cells with the Zn-CdS buffer layers deposited using zinc nitrate and zinc acetate additives.