

## Supporting Information

**Table 1.** Summary of reported WBG PSCs from 2020 to now.

$E_g$ (eV)	$V_{oc}$ (V)	PCE (%)	Ref.
1.77	1.113	14.1	1
1.77	1.197	16.4	2
1.79	1.26	17.80	3
1.79	1.25	17.6	4
1.8	1.263	17.7	5
1.85	1.34	16.8	6
1.75	1.33	20.3	7
1.68	1.2	20.96	8
1.78	1.324	19.6	9
1.78	1.36	19.83	10
1.73	1.3	21.3	
1.79	1.34	19.5	11
1.85	1.36	18.1	
1.92	1.39	16.2	
1.66	1.23	21.47	12
1.85	1.35	18.87	13
1.79	1.33	19.3	14
1.77	1.31	18.46	15
1.78	1.29	18.59	
1.75	1.29	20.1	16
1.68	1.216	22.35	17
1.67	1.25	22.06	18
1.84	1.326	17.96	
1.68	1.22	21.72	19
1.88	1.36	18.4	
1.77	1.34	19.31	20
1.78	1.25	17.83	21
1.82	1.32	18.69	
1.77	1.3	20.1	22
1.71	1.25	21.97	23
1.77	1.296	19.45	24
1.66	1.27	22.40	25
1.67	1.272	22.00	26
1.65	1.24	21.55	27
1.68	1.215	21.10	28
1.77	1.339	18.88	29
1.67	1.262	21.8	30

1.79	1.32	20.06	31
1.68	1.256	21.9	32
1.7	1.24	20.6	33
1.8	1.34	20.3	34
1.81	1.351	19.58	35
1.83	1.32	18.96	36
1.77	1.35	18.7	37
1.79	1.35	19.50	38
1.9	1.305	17.05	39
1.86	1.366	18.52	40
1.77	1.29	19.30	40
1.68	1.25	23.05	41
1.65	1.24	21.55	42
1.7	1.30	21.54	43
1.8	1.33	19.16	43
1.75	1.32	20.80	44
1.66	1.3	24.3	45
1.67	1.29	24.48	46
1.67	1.24	23.1	47
1.75	1.29	19.7	47
1.67	1.25	23.18	48
1.8	1.30	19.0	49
1.77	1.314	19.32	50
1.72	1.201	15.90	51
1.79	1.33	19.08	52
1.88	1.44	19.17	53
1.85	1.361	18.45	54
1.85	1.387	18.76	55
1.8	1.37	20.4	56
1.84	1.315	17.48	57
1.72	1.30	21.39	58
1.84	1.36	19.64	58
1.80	1.31	18.79	58
1.86	1.33	18.38	59
1.88	1.36	18.39	59

**Table 2.** Summary of the photovoltaic parameters of the reported OSCs.

$V_{OC}$ (V)	$J_{SC}$ (mA/cm <sup>2</sup> )	FF (%)	PCE (%)	Ref.
0.92	27.41	80.62	20.51	60
0.937	27.2	80.8	20.6	61
0.891	27.99	80.3	20.03	62
0.92	27.2	80.8	20.2	63

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0.924	26.77	81.85	20.25	64
0.896	27.79	81.3	20.2	65
0.894	27.96	81.7	20.42	66
0.884	28.45	80.6	20.28	67
0.92	26.98	81	20.09	68
0.919	27.2	80.7	20.2	69
0.863	29.1	80.52	20.22	70
0.92	26.9	80.9	20	71
0.876	29.16	81.49	20.82	72
0.906	27.7	79.6	20	73
0.93	27.9	77.4	20.1	74
0.92	26.75	81	20	75
0.94	26.59	80.23	20.04	76
0.869	28.6	80.6	20.1	77
0.938	26.7	82.1	20.6	78
0.917	26.8	80.2	20.2	79
0.898	27.77	80.5	20.07	80
0.91	27.5	82	20.5	81
0.91	27.41	80.23	20.01	82
0.873	28.07	81.6	20	83
0.904	27.2	81.8	20.11	84
0.906	26.5	81.2	20.1	85
0.931	26.81	80.6	20.12	86
0.942	27.85	78.35	20.5	87
0.879	28.55	81.33	20.52	88
0.908	27.3	81	20.1	89
0.91	26.2	80.3	20.1	90
0.914	26.8	82.8	21	91
0.926	27.11	80.13	20.13	92
0.861	28.89	80.41	20	93
0.918	26.25	83	20.05	94
0.923	27.9	80.8	20.8	95
0.914	27.34	80.34	20.08	96
0.87	31.83	74.03	20.44	97
0.886	28.48	79.79	20.12	98
0.907	27.23	82.6	20.42	99
0.932	26.91	81.92	20.55	100
0.864	28.98	80.3	20.1	101
0.863	28.83	80.64	20.06	102
0.88	28.4	80.86	20.17	103
0.891	27.8	81.5	20.2	104
0.896	28.23	79.11	20	105
0.88	28.6	79.6	20.3	106
0.87	29.49	79.2	20.32	107

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0.89	28.65	81.5	20.78	108
0.867	28.71	83.58	20.8	109
0.915	27.23	82.4	20.53	110

**Table 3.** Summary of reported POTSCs.

Device structure	Perovskite/ organic $E_g$ (eV)	PCE (%)	Ref.
p-i-n			
ITO/PTAA/Cs <sub>0.1</sub> (FA <sub>0.6</sub> MA <sub>0.4</sub> ) <sub>0.9</sub> Pb(I <sub>0.6</sub> Br <sub>0.4</sub> ) <sub>3</sub> /PC <sub>61</sub> BM /BCP/Ag/M-PEDOT/PBDB-T:SN6IC-4F/Bis- C <sub>60</sub> /BCP/Ag	1.74/1.30	15.13	111
ITO/NiOx/FA <sub>0.8</sub> MA <sub>0.02</sub> Cs <sub>0.18</sub> PbI <sub>1.8</sub> Br <sub>1.2</sub> /C <sub>60</sub> /BCP/Ag/ MoOx/PM6:Y6:PC <sub>71</sub> BM/TPBi/Ag	1.77/1.33	20.6 (certified 19.64)	1
ITO/2PACz/FA <sub>0.8</sub> MA <sub>0.4</sub> Pb(I <sub>0.6</sub> Br <sub>0.4</sub> ) <sub>3</sub> /C <sub>60</sub> /BCP/Ag/Mo Ox/PTB7-Th:BTPV-4CI-eC9/PDINN/Ag	1.79/1.22	22.0	4
ITO/NiOx/BPA/Cs <sub>0.25</sub> FA <sub>0.75</sub> Pb(I <sub>0.6</sub> Br <sub>0.4</sub> ) <sub>3</sub> /C <sub>60</sub> /BCP/IZ O/MoOx/PM6:Y6:PC <sub>71</sub> BM/PNDIT-F3N/Ag	1.79/1.33	23.60 (certified 22.95)	3
ITO/poly- TPD/MA <sub>0.96</sub> FA <sub>0.1</sub> PbI <sub>2</sub> Br(SCN) <sub>0.12</sub> /PCBM/BCP/Au/ MoO <sub>3</sub> /PM6:CH1007/PFN-Br/Ag	1.72/1.3	21.2	112
ITO/Poly- TPD/MA <sub>1.06</sub> PbI <sub>2</sub> Br(SCN) <sub>0.12</sub> /PCBM/BCP/Au/ MoO <sub>3</sub> /PM6:Y6/PFN-Br/Ag	1.71/1.33	20.03	113
ITO/MeO- 2PACz/FA <sub>0.8</sub> Cs <sub>0.2</sub> Pb(I <sub>0.5</sub> Br <sub>0.5</sub> ) <sub>3</sub> /PEAI/PC <sub>61</sub> BM/AZO- NP/SnOx/InOx /MoOx/PM6:Y6:PC <sub>61</sub> BM/C <sub>60</sub> /BCP/Ag	1.85/1.33	24.0 (certified 23.1)	6
ITO/MeO- 2PACz/FA <sub>0.8</sub> Cs <sub>0.2</sub> PbI <sub>1.8</sub> Br <sub>1.2</sub> /TEACI/C <sub>60</sub> /ALD- SnO <sub>2</sub> /Au/PEDOT:PSS/PM6:Y6/ PFN-Br <sub>2</sub> /Ag	1.79/1.33	22.29	114
ITO/poly-TPD modified NiOx/BA <sub>1.8</sub> PE <sub>0.2</sub> MA <sub>2.5</sub> Pb <sub>3.5</sub> I <sub>11.5</sub> /PC <sub>61</sub> BM/BCP/Au/Mo O <sub>3</sub> /PM6:BTP-eC9/PFN/Ag	1.69/1.36	21.3	115
ITO/PTAA/FA <sub>0.9</sub> Cs <sub>0.1</sub> Pb(I <sub>0.6</sub> Br <sub>0.4</sub> ) <sub>3</sub> /PCBM/ALD- SnO <sub>2</sub> /Au/PEDOT:PSS/PM6:BTP-eC9/C <sub>60</sub> /BCP/Ag	1.8/1.36	22.25	116
ITO/NiOx/2PACz/FA <sub>0.8</sub> Cs <sub>0.2</sub> Pb(I <sub>0.5</sub> Br <sub>0.5</sub> ) <sub>3</sub> /C <sub>60</sub> /BCP/A u/MoOx/PM6:PM7:Y6:PC <sub>71</sub> BM/C <sub>60</sub> /BCP/Ag	1.85/1.33	24.47	13
ITO/MeO- 2PACz/ALO/FA <sub>0.6</sub> MA <sub>0.4</sub> Pb(I <sub>0.6</sub> Br <sub>0.4</sub> ) <sub>3</sub> /PCBM/SnO <sub>x</sub> /P ED/PM6:Y6/PDINN/Ag	1.77/1.33	22.31	117
ITO/NiOx/FA <sub>0.6</sub> MA <sub>0.4</sub> Pb(I <sub>0.7</sub> Br <sub>0.3</sub> ) <sub>3</sub> /PC <sub>61</sub> BM/NDI- NI/Ag/MoO <sub>3</sub> /PM6:L8-BO:LBz-F/NDI- NI/Ag	1.72/1.40	22.11	51

glass/ITO/DC- PA/Cs <sub>0.2</sub> FA <sub>0.8</sub> Pb(I <sub>0.6</sub> Br <sub>0.4</sub> ) <sub>3</sub> /C <sub>60</sub> /BCP/Au/MoO <sub>x</sub> /PM6: Y6:PC <sub>71</sub> BM/PNDIT-F3N/Ag ITO/NiO <sub>x</sub> /CbzNaph/i-	1.81/N/A	25.22 (certified 24.27)	35
PVK/C <sub>60</sub> /SnO <sub>x</sub> /Au/MoO <sub>x</sub> /PM6:BTP- eC9:PCBM/PNDIT-F3N/Ag ITO/NiO <sub>x</sub> /Me-4PACz/WBG	1.78/N/A	23.24	118
perovskite/PCBM/AZO/ITO/MoO <sub>x</sub> /PM6:BTP- eC9/PDINN/Ag	1.86/1.36	25.13 (certified 23.4)	39
ITO/4PADCB/FAMACsPb(I <sub>0.5</sub> Br <sub>0.5</sub> ) <sub>3</sub> /PC <sub>60</sub> BM/C <sub>60</sub> /S nO <sub>x</sub> /Au/PEDOT:PSS/D18:L8-BO:BTP-eC9- 4F/PDINN/Ag	N/A	24.5	119
ITO/NiO <sub>x</sub> /Me-2PACz/WBG perovskite/C <sub>60</sub> /BCP/Au/5 nm MoO <sub>x</sub> /PM6:D18:Y6:L8-BO & Me- 4PACz/C <sub>60</sub> /BCP/Ag	1.84/N/A	25.56 (certified 24.65)	<a href="#">120ht</a> <a href="#">tps://</a> <a href="#">doi.or</a> <a href="#">g/10.1</a> <a href="#">002/a</a> <a href="#">dma.2</a> <a href="#">02410</a> <a href="#">692</a>
FTO/Me-4PACz/WBG perovskite/C <sub>60</sub> /SnO <sub>x</sub> /Au/PEDOT/PM6:BTPSe- Ph4F/PDINN/Ag	1.88/1.27	26.4 (certified 25.7)	121
ITO/CbzNaph/Cs <sub>0.2</sub> FA <sub>0.8</sub> Pb(I <sub>0.6</sub> Br <sub>0.4</sub> ) <sub>3</sub> / BCP/Au/MoO <sub>x</sub> /PM6:BTP-eC9:PC <sub>71</sub> BM/PNDIT-F <sub>3</sub> N/Ag	1.79/N/A	25.54	38
ITO/NiO <sub>x</sub> /2PACz/perovskite/C <sub>60</sub> /BCP/Ag/MoO <sub>3</sub> /2P ACz/PM6:D18:BTP-eC9/C <sub>60</sub> /BCP/Ag	1.82/N/A	25.92	122
ITO/Me- 4PACz/Al <sub>2</sub> O <sub>3</sub> /Cs <sub>0.2</sub> FA <sub>0.8</sub> PbI <sub>1.7</sub> Br <sub>1.3</sub> /C <sub>60</sub> /SnO <sub>2</sub> /Ag/PE DOT:PSS/2PACz/PM6:BTP-eC9/PNDIT-F3N/Ag	N/A	25.26	123
ITO/Me- 4PACz/Cs <sub>0.25</sub> FA <sub>0.75</sub> Pb(Br <sub>0.5</sub> I <sub>0.5</sub> ) <sub>3</sub> /C <sub>60</sub> /BCP/Ag/MoO <sub>3</sub> / TCB-treated SAM/PM6:BTP-eC9/C <sub>60</sub> /BCP/Ag	N/A	26.09	102
ITO/NiO <sub>x</sub> /4PADCB/perovskite/EDADI/C60/PEI/IT O/V <sub>2</sub> O <sub>5</sub> or MoO <sub>3</sub> /PM6:BTP-eC9:PC <sub>71</sub> BM/TPMA/Ag	1.79/N/A	25.1	52
ITO/SAM/FA <sub>0.8</sub> MA <sub>0.1</sub> Cs <sub>0.1</sub> PbI <sub>0.5</sub> Br <sub>0.5</sub> /C <sub>60</sub> /SnO <sub>2</sub> /Au/S AM/MoO <sub>3</sub> /SAM/PM6:BTP-eC9:L8-BO/PNDIT- F3N/Ag	1.85/1.37	26.05 (certified 24.53)	54
FTO/SAM/WBG/C60/ALD-SnO <sub>x</sub> /Au/(3,4- ethylenedioxythiophene):poly(styrenesulfonate) (PEDOT:PSS)/ PM6:BTP-eC9/PNDIT-F3N/Ag	1.85/ N/A	25.98	55
glass/ITO/SAM/perovskite/C <sub>60</sub> /SnO <sub>x</sub> /ITO/MoO <sub>x</sub> /orga nic/PDINN/Ag.	1.8/1.27	27.5 26.7 (certified 26.4 1.019 cm <sup>2</sup> )	56

ITO/Me- 4PACz/Perovskite/C <sub>60</sub> /SnO <sub>x</sub> /ITO/MoO <sub>x</sub> /PM6:Y18/P DINN/Ag	1.84/1.38	26.46 (certified 25.82)	57
ITO/Me-2PACz/WBG- perovskite/C <sub>60</sub> /SnO <sub>2</sub> /Au/MoO <sub>3</sub> /2PACz/PM6:BTP- eC9:ICBA/PDINO/Ag	1.84/N/A	26.11 (certified 25.07)	58
ITO/4PADCB/WBG/PVK/C <sub>60</sub> /SnO <sub>x</sub> /Au/PEDOT:PS S/BHJ/PDINN/Ag	1.88/1.47 1.86/1.43 1.80/1.42	26.08 25.50 25.82	59
ITO/NiO <sub>x</sub> /2PACz/WBG perovskite/PEAI/C <sub>60</sub> /BCP/Ag/MoO <sub>3</sub> /2PACz/D18- Cl:N3:PC <sub>61</sub> BM/C <sub>60</sub> /BCP/Ag	1.83/1.38	25.82 (certified 25.06)	36
n-i-p			
ITO/ZnO/SnO <sub>2</sub> /CsPbI <sub>2</sub> Br/PDCBT/MoO <sub>3</sub> /Ag/ZnO/P M6:Y6/MoO <sub>3</sub> /Ag	1.9/1.33	18.38	124
ITO/ZnO/CsPbI <sub>2</sub> Br/P3HT/MoO <sub>x</sub> /Au/ZnO/PTB7- Th:IEICO-4F/MoO <sub>x</sub> /Ag	1.85/1.25	18.04	125
ITO/SnO <sub>2</sub> /CsPbI <sub>2</sub> Br/P3HT/MoO <sub>3</sub> /Ag/PFN- Br/PTB7-Th:IEICO-4F/MoO <sub>3</sub> /Ag	1.85/1.25	17.24	126
ITO/SnO <sub>2</sub> /ZnO/CsPbI <sub>2</sub> Br/PTAA/MoO <sub>3</sub> /Au/ ZnO NPs/D18:Y6/MoO <sub>3</sub> /Ag	1.92/1.33	20.18	127
ITO/SnO <sub>2</sub> /CsPbI <sub>2</sub> Br0.9/PMACl/PBDB- T/MoO <sub>3</sub> /Ag/ ZnO NP/PM6:Y6/MoO <sub>3</sub> /Ag	1.79/1.33	18.06	128
ITO/ZnO/CsPbI <sub>2</sub> Br/polyTPD/MoO <sub>3</sub> /Ag/ PFN-Br/PM6:Y6-BO/MoO <sub>3</sub> /Ag	1.92/1.33	21.1	129
ITO/SnO <sub>2</sub> /CsPbI <sub>1.8</sub> Br1.2/TACl/PBDB-T/MoO <sub>3</sub> /Au/ ZnO/PFN/PM6:Y6/MoO <sub>3</sub> /Al	1.93/1.33	21.04	130
ITO/ZnO/SnO <sub>2</sub> /CsPbI <sub>2</sub> Br/PTAA/MoO <sub>3</sub> /Ag/PFN- Br/PM6:Y6/MoO <sub>3</sub> /Ag	1.92/1.33	20.6	131
ITO/SnO <sub>2</sub> /CsPbI <sub>2</sub> Br/PTQ10/MoO <sub>3</sub> /Ag/PFN- Br/PM6:Y6/MoO <sub>3</sub> /Ag	1.92/1.33	21.4	132
ITO/SnO <sub>2</sub> /CsPbI <sub>x</sub> Br <sub>3-x</sub> /PFBTI/MoO <sub>3</sub> /Au/ ZnO/PFN/PM6:Y6/MoO <sub>3</sub> /Ag	1.92/1.33	22.2	133
ITO/ZnO/SnO <sub>2</sub> /CsPbI <sub>1.9</sub> Br1.1/D18-Cl/MoO <sub>3</sub> /Au /ZnO/PFN/D18-Cl:N3:PC <sub>61</sub> BM/MoO <sub>3</sub> /Al	1.91/1.32	23.17	134
ITO/ZnO/SnO <sub>2</sub> /MAAc/CsPBI <sub>2.2</sub> Br0.8/PDCBT/Mo O <sub>3</sub> /Au /ZnO/BCP/PM6:CH1007/MoO <sub>3</sub> /Ag	1.88/1.3	22.43 (certified 21.42)	135
ITO/ZnO/SnO <sub>2</sub> /MAFm/CsPbI <sub>2</sub> Br/MAFm/PDCBT/M oO <sub>3</sub> /Au/ ZnO/BCP/PM6:CH1007/MoO <sub>3</sub> /Ag	1.92/1.3	23.21	136

ITO/ZnO/SnO <sub>2</sub> /CsPbI <sub>2</sub> Br/PTAA/MoO <sub>3</sub> /Ag/DPC/D18 :L8-BO/MoO <sub>3</sub> /Ag	1.92/1.40	21.7	137
FTO/c-TiO <sub>2</sub> /mp-TiO <sub>2</sub> /γ-CsPbI <sub>2.2</sub> Br <sub>0.8</sub> /PTACl/PBDB- T/MoO <sub>3</sub> /Ag/PDIN/ZnO/PM6:Y6:PCBM/MoO <sub>3</sub> /Ag	1.8/N/A	23.07	138
ITO/ZnO/SnO <sub>2</sub> /CsPbI <sub>2</sub> Br/IDTT- PhCz/MoO <sub>3</sub> /Ag/PFN-Br/PM6:BTP- eC9:PC71BM/MoO <sub>3</sub> /Ag	N/A	25.0 (certified 24.66)	139
ITO/ZnO/SnO <sub>2</sub> /MAPA/CsPbI <sub>2.2</sub> Br <sub>0.8</sub> /PDCBT/MoO <sub>3</sub> / Au/ZnO/BCP/PM6: mBzS-4F/MoO <sub>3</sub> /Ag	N/A	23.19	140
glass/ITO/ZnO/SnO <sub>2</sub> /CsPbI <sub>2</sub> Br/ICLS/D18-Cl:L8- BO/Cl-2PACz/MoO <sub>x</sub> /Ag	1.89 /1.41	25.34	141
ITO/4PADCB/WBG			
Perovskite/PCBM/C <sub>60</sub> /SnO <sub>x</sub> /PEDOT:PSS/NBG Organic/PDINN/Ag	1.85/N/A	24.03	142
ITO/ZnO/CsPbI <sub>2</sub> Br/PM6/MoO <sub>3</sub> /Ag/PFN- Br/PM6:Y6:PC71BM/MoO <sub>3</sub> /Ag	1.88/N/A	23.21	143
TO/Cl@MZO/CsPbI <sub>2</sub> Br/PM6/MoO <sub>3</sub> /Ag/PFN- Br/PM6:BTP-BO-4Cl:PC <sub>71</sub> BM/MoO <sub>3</sub> /Ag	1.92/N/A	24.1	144
glass substrate/m-FTO/M- SQDs/CsPbI <sub>2</sub> Br/PTQ10/MoO <sub>x</sub> /Ag/ZnO/PFN- Br/PM6:BTP-eC9/MoO <sub>x</sub> /Ag	1.88/ N/A	25.9 (certified 25.1)	53

## References

1. X. Chen, Z. Jia, Z. Chen, T. Jiang, L. Bai, F. Tao, J. Chen, X. Chen, T. Liu and X. Xu, *Joule*, 2020, **4**, 1594-1606.
2. K. Xiao, R. Lin, Q. Han, Y. Hou, Z. Qin, H. T. Nguyen, J. Wen, M. Wei, V. Yeddu and M. I. Saidaminov, *Nat. Energy*, 2020, **5**, 870-880.
3. W. Chen, Y. Zhu, J. Xiu, G. Chen, H. Liang, S. Liu, H. Xue, E. Birgersson, J. W. Ho and X. Qin, *Nat. Energy*, 2022, **7**, 229-237.
4. S. Qin, C. Lu, Z. Jia, Y. Wang, S. Li, W. Lai, P. Shi, R. Wang, C. Zhu and J. Du, *Adv. Mater.*, 2022, **34**, 2108829.
5. J. Wen, Y. Zhao, Z. Liu, H. Gao, R. Lin, S. Wan, C. Ji, K. Xiao, Y. Gao and Y. Tian, *Adv. Mater.*, 2022, **34**, 2110356.
6. K. Brinkmann, T. Becker, F. Zimmermann, C. Kreuzel, T. Gahlmann, M. Theisen, T. Haeger, S. Olthof, C. Tückmantel and M. Günster, *Nature*, 2022, **604**, 280-286.
7. Q. Jiang, J. Tong, R. A. Scheidt, X. Wang, A. E. Louks, Y. Xian, R. Tirawat, A. F. Palmstrom, M. P. Hautzinger and S. P. Harvey, *Science*, 2022, **378**, 1295-1300.
8. T. Han, W. Zhu, T. Wang, M. Yang, Y. Zhou, H. Xi, P. Zhong, D. Chen, J. Zhang and C. Zhang, *Adv. Funct. Mater.*, 2024, **34**, 2311679.
9. J. Wen, Y. Zhao, P. Wu, Y. Liu, X. Zheng, R. Lin, S. Wan, K. Li, H. Luo and Y. Tian, *Nat. Commun.*, 2023, **14**, 7118.
10. H. Cui, L. Huang, S. Zhou, C. Wang, X. Hu, H. Guan, S. Wang, W. Shao, D. Pu and K. Dong,

- Energy Environ. Sci.*, 2023, **16**, 5992-6002.
11. Y. An, N. Zhang, Z. Zeng, Y. Cai, W. Jiang, F. Qi, L. Ke, F. R. Lin, S. W. Tsang and T. Shi, *Adv. Mater.*, 2024, **36**, 2306568.
  12. H. Guan, W. Zhang, J. Liang, C. Wang, X. Hu, D. Pu, L. Huang, Y. Ge, H. Cui and Y. Zou, *Adv. Funct. Mater.*, 2023, **33**, 2300860.
  13. X. Wang, D. Zhang, B. Liu, X. Wu, X. Jiang, S. Zhang, Y. Wang, D. Gao, L. Wang and H. Wang, *Adv. Mater.*, 2023, **35**, 2305946.
  14. H. Chen, A. Maxwell, C. Li, S. Teale, B. Chen, T. Zhu, E. Ugur, G. Harrison, L. Grater and J. Wang, *Nature*, 2023, **613**, 676-681.
  15. R. He, W. Wang, Z. Yi, F. Lang, C. Chen, J. Luo, J. Zhu, J. Thiesbrummel, S. Shah and K. Wei, *Nature*, 2023, **618**, 80-86.
  16. J. Yong, Y. K. Lee, H. Park, S. Muthu, J. Shin, D. R. Whang, B. G. Kim, D. W. Chang and H. J. Park, *Adv. Funct. Mater.*, 2024, **34**, 2312505.
  17. L. Yang, Z. Fang, Y. Jin, H. Feng, B. Deng, L. Zheng, P. Xu, J. Chen, X. Chen and Y. Zhou, *Adv. Mater.*, 2024, **36**, 2311923.
  18. P. Jia, G. Chen, G. Li, J. Liang, H. Guan, C. Wang, D. Pu, Y. Ge, X. Hu and H. Cui, *Adv. Mater.*, 2024, **36**, 2400105.
  19. X. Li, Y. Li, Y. Feng, J. Qi, J. Shen, G. Shi, S. Yang, M. Yuan and T. He, *Adv. Mater.*, 2024, **36**, 2401103.
  20. X. Jiang, Q. Zhou, Y. Lu, H. Liang, W. Li, Q. Wei, M. Pan, X. Wen, X. Wang and W. Zhou, *Natl. Sci. Rev.*, 2024, **11**, nwae055.
  21. Q. Sun, Z. Zhang, H. Yu, J. Huang, X. Li, L. Dai, Q. Wang, Y. Shen and M. Wang, *Energy Environ. Sci.*, 2024, **17**, 2512-2520.
  22. P. Chen, Y. Xiao, J. Hu, S. Li, D. Luo, R. Su, P. Caprioglio, P. Kaienburg, X. Jia and N. Chen, *Nature*, 2024, **625**, 516-522.
  23. Q. Ma, Y. Wang, L. Liu, P. Yang, W. He, X. Zhang, J. Zheng, M. Ma, M. Wan and Y. Yang, *Energy Environ. Sci.*, 2024, **17**, 1637-1644.
  24. D. Pu, S. Zhou, H. Guan, P. Jia, G. Chen, H. Fang, S. Fu, C. Wang, H. Hushvaktov and A. Jumabaev, *Adv. Funct. Mater.*, 2024, **34**, 2314349.
  25. H. Guan, S. Zhou, S. Fu, D. Pu, X. Chen, Y. Ge, S. Wang, C. Wang, H. Cui and J. Liang, *Adv. Mater.*, 2024, **36**, 2307987.
  26. L. Qiao, T. Ye, T. Wang, W. Kong, R. Sun, L. Zhang, P. Wang, Z. Ge, Y. Peng and X. Zhang, *Adv. Energy Mater.*, 2024, **14**, 2302983.
  27. G. Su, R. Yu, Y. Dong, Z. He, Y. Zhang, R. Wang, Q. Dang, S. Sha, Q. Lv and Z. Xu, *Adv. Energy Mater.*, 2024, **14**, 2303344.
  28. C. Li, Z. Zhang, H. Zhang, W. Yan, Y. Li, L. Liang, W. Yu, X. Yu, Y. Wang and Y. Yang, *Angew. Chem. Int. Ed.*, 2024, **63**, e202315281.
  29. Z. Yi, W. Wang, R. He, J. Zhu, W. Jiao, Y. Luo, Y. Xu, Y. Wang, Z. Zeng and K. Wei, *Energy Environ. Sci.*, 2024, **17**, 202-209.
  30. Z. Liu, H. Li, Z. Chu, R. Xia, J. Wen, Y. Mo, H. Zhu, H. Luo, X. Zheng and Z. Huang, *Adv. Mater.*, 2024, **36**, 2308370.
  31. L. Qiao, T. Ye, P. Wang, T. Wang, L. Zhang, R. Sun, W. Kong and X. Yang, *Adv. Funct. Mater.*, 2024, **34**, 2308908.
  32. R. Wang, J. Zhu, J. You, H. Huang, Y. Yang, R. Chen, J. Wang, Y. Xu, Z. Gao and J. Chen,

- Energy Environ. Sci.*, 2024, **17**, 2662-2669.
33. H. Sun, S. Liu, X. Liu, Y. Gao, J. Wang, C. Shi, H. Raza, Z. Sun, Y. Pan and Y. Cai, *Small Methods*, 2024, **8**, 2400067.
  34. F. Yang, P. Tockhorn, A. Musiienko, F. Lang, D. Menzel, R. Macqueen, E. Köhnen, K. Xu, S. Mariotti and D. Mantione, *Adv. Mater.*, 2024, **36**, 2307743.
  35. S. Wu, Y. Yan, J. Yin, K. Jiang, F. Li, Z. Zeng, S.-W. Tsang and A. K.-Y. Jen, *Nat. Energy*, 2024, **9**, 411-421.
  36. Z. Zhang, W. Chen, X. Jiang, J. Cao, H. Yang, H. Chen, F. Yang, Y. Shen, H. Yang and Q. Cheng, *Nat. Energy*, 2024, **9**, 592-601.
  37. Y.-H. Lin, Vikram, F. Yang, X.-L. Cao, A. Dasgupta, R. D. Oliver, A. M. Ulatowski, M. M. McCarthy, X. Shen and Q. Yuan, *Science*, 2024, **384**, 767-775.
  38. M. Chen, Y. Li, Z. Zeng, M. Liu, T. Du, X. Huang, L. Bi, J. Wang, W. Jiang and Y. An, *Energy Environ. Sci.*, 2024, **17**, 9580-9589.
  39. X. Guo, Z. Jia, S. Liu, R. Guo, F. Jiang, Y. Shi, Z. Dong, R. Luo, Y.-D. Wang and Z. Shi, *Joule*, 2024, **8**, 2554-2569.
  40. Y. Luo, J. Zhu, X. Yin, W. Jiao, Z. Gao, Y. Xu, C. Wang, Y. Wang, H. Lai and H. Huang, *Adv. Energy Mater.*, 2024, **14**, 2304429.
  41. T. Huang, F. Xu, J. Hu, J. Wu, S. Li, P. Chen, X. Jia, Q. Li, H. Yan and Y. Ji, *Energy Environ. Sci.*, 2024, **17**, 5984-5992.
  42. G. Su, R. Yu, Y. Dong, Z. He, Y. Zhang, R. Wang, Q. Dang, S. Sha, Q. Lv, Z. Xu, Z. Liu, M. Li and Z. a. Tan, *Adv. Energy Mater.*, 2023, **14**.
  43. M. Lee, J. Lim, E. Choi, A. M. Soufiani, S. Lee, F. J. Ma, S. Lim, J. Seidel, D. H. Seo, J. S. Park, W. Lee, J. Lim, R. F. Webster, J. Kim, D. Wang, M. A. Green, D. Kim, J. H. Noh, X. Hao and J. S. Yun, *Adv. Mater.*, 2024, **36**, e2402053.
  44. R. Wang, X. Liu, S. Yan, N. Meng, X. Zhao, Y. Chen, H. Li, S. M. Qaid, S. Yang and M. Yuan, *Nat. Commun.*, 2024, **15**, 8899.
  45. Z. Wang, Z. Han, X. Chu, H. Zhou, S. Yu, Q. Zhang, Z. Xiong, Z. Qu, H. Tian and W. Wang, *Adv. Mater.*, 2024, **36**, 2407681.
  46. Z. Fang, B. Deng, Y. Jin, L. Yang, L. Chen, Y. Zhong, H. Feng, Y. Yin, K. Liu and Y. Li, *Nat. Commun.*, 2024, **15**, 10554.
  47. S. Li, Z. Zheng, J. Ju, S. Cheng, F. Chen, Z. Xue, L. Ma and Z. Wang, *Adv. Mater.*, 2024, **36**, 2307701.
  48. L. Liu, B. Farhadi, J. Li, S. Liu, L. Lu, H. Wang, M. Du, L. Yang, S. Bao and X. Jiang, *Angew. Chem. Int. Ed.*, 2024, **63**, e202317972.
  49. K. Zhang, C. Liu, Z. Peng, C. Li, J. Tian, C. Li, J. G. Cerrillo, L. Dong, F. Streller and A. Späth, *Joule*, 2024, **8**, 2863-2882.
  50. Z. Gao, Y. Zhu, J. Zhu, C. Chen, Z. Yi, Y. Luo, Y. Xu, K. Wu, T. Ma and F. Cao, *J. Energy Chem.*, 2024, **96**, 120-128.
  51. W. Liu, Y. Duan, Z. Zhang, J. Gao, S. Li, Z. Fink, X. Wu, Z. Ma, A. Sacki and T. P. Russell, *ACS Energy Lett.*, 2023, **8**, 4514-4523.
  52. Z. He, R. Yu, Y. Dong, R. Wang, Y. Zhang and Z. a. Tan, *Nat. Commun.*, 2025, **16**, 1773.
  53. Y. Han, J. Fu, Z. Ren, J. Yu, Q. Liang, Z. Xu, X. Xie, D. Li, R. Ma and M. Cao, *Nat. Energy*, 2025, 1-13.
  54. Y. An, N. Zhang, Q. Liu, W. Jiang, G. Du, D. Chen, M. Liu, X. Huang, T. Lei and Q. Qiu, *Nat.*

- Commun.*, 2025, **16**, 1-11.
55. Z. Song, J. Wang, Y. Bao, J. Zeng, D. Wang, J. He, P. Zhu, B. Jiang, Z. Liu and S. He, *Energy Environ. Sci.*, 2025, **18**, 4883-4892.
  56. Z. Jia, X. Guo, X. Yin, M. Sun, J. Qiao, X. Jiang, X. Wang, Y. Wang, Z. Dong and Z. Shi, *Nature*, 2025, 1-7.
  57. Y.-D. Wang, Z. Jia, S. Liu, R. Luo, Y. Zhang, J. A. Steele, Z. Degnan, M. Bilal Faheem, E. Solano and Q. Qiao, *Nat. Commun.*, 2025, **16**, 6142.
  58. Q. Ye, B. Fan, Y. Zhou, S. Liu, S. Yao, J. Lv, C. Wang, R. Dai, D. Chen and X. Meng, *Adv. Mater.*, 2025, e11781.
  59. N. Wei, Z. Gao, F. Qi, H. Song, B. Shang, X. Wang, J. Chen, X. Deng, X. Cui and Y. Liu, *Adv. Mater.*, 2025, e08611.
  60. X. Gu, Y. Wei, R. Zeng, J. Lv, Y. Hou, N. Yu, S. Tan, Z. Wang, C. Li and Z. Tang, *Angew. Chem. Int. Ed.*, 2025, **64**, e202418926.
  61. Y. Jiang, K. Liu, F. Liu, G. Ran, M. Wang, T. Zhang, R. Xu, H. Liu, W. Zhang and Z. Wei, *Adv. Mater.*, 2025, **37**, 2500282.
  62. R. Ma, B. Zou, Y. Hai, Y. Luo, Z. Luo, J. Wu, H. Yan and G. Li, *Adv. Mater.*, 2025, **37**, 2500861.
  63. Y. Jiang, S. Sun, R. Xu, F. Liu, X. Miao, G. Ran, K. Liu, Y. Yi, W. Zhang and X. Zhu, *Nat. Energy*, 2024, **9**, 975-986.
  64. C. Li, G. Yao, X. Gu, J. Lv, Y. Hou, Q. Lin, N. Yu, M. S. Abbasi, X. Zhang and J. Zhang, *Nat. Commun.*, 2024, **15**, 8872.
  65. J. Ren, J. Wang, J. Qiao, Z. Chen, X. Hao, S. Zhang and J. Hou, *Adv. Mater.*, 2025, **37**, 2418353.
  66. C. Li, J. Song, H. Lai, H. Zhang, R. Zhou, J. Xu, H. Huang, L. Liu, J. Gao and Y. Li, *Nat. Mater.*, 2025, **24**, 433-443.
  67. J. Liu, X. Duan, J. Zhang, Z. Ge, L. Liu, J. Qiao, Y. Li, Z. Bi, H. Zhang and J. Gao, *Angew. Chem.*, 2025, e202500129.
  68. H. Lu, D. Li, W. Liu, G. Ran, H. Wu, N. Wei, Z. Tang, Y. Liu, W. Zhang and Z. Bo, *Angew. Chem. Int. Ed.*, 2024, **63**, e202407007.
  69. Y. Sun, L. Wang, C. Guo, J. Xiao, C. Liu, C. Chen, W. Xia, Z. Gan, J. Cheng and J. Zhou, *J. Am. Chem. Soc.*, 2024, **146**, 12011-12019.
  70. Z. Chen, J. Ge, W. Song, X. Tong, H. Liu, X. Yu, J. Li, J. Shi, L. Xie and C. Han, *Adv. Mater.*, 2024, **36**, 2406690.
  71. B. Cheng, W. Hou, C. Han, S. Cheng, X. Xia, X. Guo, Y. Li and M. Zhang, *Energy Environ. Sci.*, 2025, **18**, 1375-1384.
  72. H. Chen, Y. Huang, R. Zhang, H. Mou, J. Ding, J. Zhou, Z. Wang, H. Li, W. Chen and J. Zhu, *Nat. Mater.*, 2025, **24**, 444-453.
  73. J. Wang, P. Wang, T. Chen, W. Zhao, J. Wang, B. Lan, W. Feng, H. Liu, Y. Liu and X. Wan, *Angew. Chem. Int. Ed.*, 2025, **64**, e202423562.
  74. B. Fan, H. Gao, L. Yu, R. Li, L. Wang, W. Zhong, Y. Wang, W. Jiang, H. Fu and T. Chen, *Angew. Chem. Int. Ed.*, 2025, **64**, e202418439.
  75. N. Wei, J. Chen, Y. Cheng, Z. Bian, W. Liu, H. Song, Y. Guo, W. Zhang, Y. Liu and H. Lu, *Adv. Mater.*, 2024, **36**, 2408934.
  76. W. Qiu, C. Liao, Y. Li, M. Deng, Y. Duan, X. Xu and Q. Peng, *Adv. Funct. Mater.*, 2025,

- 2503009.
77. B. Cheng, X. Xia, S. Cheng, C. Han, F. Sun, Z. Fu, W. Hou, F. Hua, H. Wang and W. Sun, *Adv. Mater.*, 2025, **37**, 2500357.
  78. M. Zhang, L. Zhu, J. Yan, X. Xue, Z. Wang, F. Eisner, G. Zhou, R. Zeng, L. Kan and L. Wu, *Joule*, 2025, **9**.
  79. N. Wei, H. Lu, Y. Wei, Y. Guo, H. Song, J. Chen, Z. Yang, Y. Cheng, Z. Bian and W. Zhang, *Energy Environ. Sci.*, 2025, **18**, 2298-2307.
  80. K. Chen, W. Duan, L. Zhou, R. Ma, P. Li, B. Zou and G. Li, *Mater. Sci. Eng. R Rep.*, 2025, **164**, 100977.
  81. X. Song, B. Zhang, X. Liu, L. Mei, H. Li, S. Yin, X. Zhou, H. Chen, Y. Lin and W. Zhu, *Adv. Mater.*, 2025, **37**, 2418393.
  82. S. Wang, S. Wang, J. Wang, N. Yu, J. Qiao, X. Xie, C. Li, M. S. Abbasi, R. Ding and X. Zhang, *Adv. Energy Mater.*, 2025, 2405205.
  83. Z. Ge, J. Qiao, Y. Li, J. Song, X. Duan, Z. Fu, H. Hu, R. Yang, H. Yin and X. Hao, *Angew. Chem.*, 2025, **137**, e202413309.
  84. L. Guo, J. Song, J. Deng, J. Qiao, J. Zhang, C. Li, S. Yuan, B. Han, M. H. Jee and Z. Ge, *Adv. Mater.*, 2025, 2504396.
  85. J. Zhou, L. Wang, C. Liu, C. Guo, C. Chen, Y. Sun, Y. Yang, J. Cheng, Z. Gan and Z. Chen, *J. Am. Chem. Soc.*, 2024, **146**, 34998-35006.
  86. W. Zou, Y. Sun, L. Sun, X. Wang, C. Gao, D. Jiang, J. Yu, G. Zhang, H. Yin and R. Yang, *Adv. Mater.*, 2025, **37**, 2413125.
  87. Z. Ling, J. Wu, J. P. Jurado, C. E. Petoukhoff, S. Y. Jeong, D. Naphade, M. Babics, X. Chang, H. Faber and S. Doukas, *Mater. Sci. Eng. R Rep.*, 2025, **163**, 100922.
  88. S. Guan, Y. Li, Z. Bi, Y. Lin, Y. Fu, K. Wang, M. Wang, W. Ma, J. Xia and Z. Ma, *Energy Environ. Sci.*, 2025, **18**, 313-321.
  89. C. Han, B. Cheng, Z. Fu, H. Wang, S. Ji, J. Wu, S. Cheng, X. Xia, H. Yin and X. Du, *Angew. Chem.*, 2025, e202501592.
  90. C. Chen, L. Wang, W. Xia, K. Qiu, C. Guo, Z. Gan, J. Zhou, Y. Sun, D. Liu and W. Li, *Nat. Commun.*, 2024, **15**, 6865.
  91. L. Wang, C. Chen, Z. Gan, J. Cheng, Y. Sun, J. Zhou, W. Xia, D. Liu, W. Li and T. Wang, *Adv. Mater.*, 2025, **37**, 2419923.
  92. Y. Wu, X. Dai, C. Liao, X. Xu and Q. Peng, *ACS Appl. Mater. Interfaces*, 2025, **17**, 22760-22769.
  93. Y. Wang, C. Gao, W. Lei, T. Yang, Z. Liang, K. Sun, C. Zhao, L. Chen, L. Zhu and H. Zeng, *Nano-Micro Lett.*, 2025, **17**, 1-19.
  94. J. Deng, W. Li, R. Zeng, J. Song, S. Tan, L. Kan, Z. Qin, Y. Zhao, F. Liu and Y. Sun, *Adv. Mater.*, 2025, 2501243.
  95. L. Zhu, M. Zhang, G. Zhou, Z. Wang, W. Zhong, J. Zhuang, Z. Zhou, X. Gao, L. Kan and B. Hao, *Joule*, 2024, **8**, 3153-3168.
  96. Y. Li, H. Li, X. Xu, L. Yu, R. Li and Q. Peng, *Adv. Funct. Mater.*, 2025, 2424327.
  97. H. Ren, J.-D. Chen, Y.-F. Zhang, J.-L. Zhang, W.-S. Chen, Y.-Q. Li and J.-X. Tang, *Sci. Adv.*, 2024, **10**, eadp9439.
  98. H. Li, Y. Li, X. Dai, X. Xu and Q. Peng, *Angew. Chem. Int. Ed.*, 2025, **64**, e202416866.
  99. X. Dai, Y. Li, H. Li, W. Zhou, X. Xu, M. Deng, C. Liao and Q. Peng, *Small*, 2025, **21**,

- 2411457.
100. X. Dai, B. Fan, W. Zhou, Y. Li, X. Xu and Q. Peng, *ACS Energy Lett.*, 2025, **10**, 2045-2051.
  101. C. Liu, J. Song, J. Gao, Z. Tang, J. Liu, H. Y. Woo, M. H. Jee and Y. Sun, *Small*, 2025, **21**, 2500230.
  102. X. Sun, F. Wang, G. Yang, X. Ding, J. Lv, Y. Sun, T. Wang, C. Gao, G. Zhang and W. Liu, *Energy Environ. Sci.*, 2025, **18**, 2536-2545.
  103. S. Guan, Y. Li, C. Xu, N. Yin, C. Xu, C. Wang, M. Wang, Y. Xu, Q. Chen and D. Wang, *Adv. Mater.*, 2024, **36**, 2400342.
  104. Y. Yu, J. Wang, Z. Chen, Y. Xiao, Z. Fu, T. Zhang, H. Yuan, X.-T. Hao, L. Ye and Y. Cui, *Sci. China Chem.*, 2024, 1-8.
  105. X. Wang, Q. Liang, A. Zhang, N. Wei, H. Jiang, Y. Cheng, H. Fang, S. Li, H. Lu and W. Li, *J. Am. Chem. Soc.*, 2025, **147**, 9261-9272.
  106. J. Xie, K. Zhang, L. Hao, Z. Yang, S. Dong, H. Li, L. Liu, J. Yu, L. Wang and J. Zhao, *Adv. Energy Mater.*, 2025, **15**, 2501819.
  107. P. Zhang, N. Gao, B. Du, Z. Xu, S. Wu, K. Zhu, X. Ma, H. Bin and Y. Li, *Angew. Chem.*, 2025, **137**, e202424430.
  108. Y. Xie, J. Tian, X. Yang, J. Chen, S. Yu, D. Tang, X. Hu, Y. Sun and M. Lv, *Adv. Mater.*, 2025, **37**, e02485.
  109. J. Dong, Y. Li, C. Liao, X. Xu, L. Yu, R. Li and Q. Peng, *Energy Environ. Sci.*, 2025, **18**, 4982-4995.
  110. Y. Yang, J. Liu, J. Song, X. Duan, J. Deng, H. Ma, J. Liu, Z. Gao, X. Xie, G. Lu, J. Zhang, Z. Chu, X. Hu, Y. Li and Y. Sun, *Angew. Chem. Int. Ed. Engl.*, 2025, 202523043, e23043.
  111. Z. Li, S. Wu, J. Zhang, K. C. Lee, H. Lei, F. Lin, Z. Wang, Z. Zhu and A. K. Jen, *Adv. Energy Mater.*, 2020, **10**, 2000361.
  112. Y. M. Xie, Q. Yao, Z. Zeng, Q. Xue, T. Niu, R. Xia, Y. Cheng, F. Lin, S. W. Tsang and A. K. Y. Jen, *Adv. Funct. Mater.*, 2022, **32**, 2112126.
  113. Y.-M. Xie, T. Niu, Q. Yao, Q. Xue, Z. Zeng, Y. Cheng, H.-L. Yip and Y. Cao, *J. Energy Chem.*, 2022, **71**, 12-19.
  114. C. Wang, W. Shao, J. Liang, C. Chen, X. Hu, H. Cui, C. Liu, G. Fang and C. Tao, *Small*, 2022, **18**, 2204081.
  115. H. Wu, T. Chen, Y. Li, S. Guan, L. Zhang, T. Chen, Y. Liu, Y. Jin, L. Zuo and W. Fu, *J. Mater. Chem. A*, 2023, **11**, 6877-6885.
  116. Y. Tang, Y. Zhang, X. Zhou, T. Huang, K. Shen, K. Zhang, X. Du, T. Shi, X. Xiao and N. Li, *Nano Energy*, 2023, **114**, 108653.
  117. G. Xie, H. Li, X. Wang, J. Fang, D. Lin, D. Wang, S. Li, S. He and L. Qiu, *Adv. Funct. Mater.*, 2023, **33**, 2308794.
  118. Y. Li, Y. Yan, Y. Fu, W. Jiang, M. Liu, M. Chen, X. Huang, G. Lu, X. Lu and J. Yin, *Angew. Chem. Int. Ed.*, 2024, **63**, e202412515.
  119. X. Cui, G. Xie, Y. Liu, X. Xie, H. Zhang, H. Li, P. Cheng, G. Lu, L. Qiu and Z. Bo, *Adv. Mater.*, 2024, **36**, 2408646.
  120. X. Wu, D. Zhang, B. Liu, Y. Wang, X. Wang, Q. Liu, D. Gao, N. Wang, B. Li and L. Wang, *Adv. Mater.*, 2024, **36**, 2410692.
  121. X. Jiang, S. Qin, L. Meng, G. He, J. Zhang, Y. Wang, Y. Zhu, T. Zou, Y. Gong and Z. Chen, *Nature*, 2024, **635**, 860-866.

122. S. Kang, Z. Wang, W. Chen, Z. Zhang, J. Cao, J. Zheng, X. Jiang, J. Xu, J. Yuan and J. Zhu, *Adv. Mater.*, 2025, **37**, 2411027.
123. S. Liu, L. Hao, J. Yu, Y. Xu, Y. Dou, J. Xie, Y. Wang, K. Zhang, F. Huang and Y. Cao, *ACS nano*, 2024, **19**, 748-759.
124. S. Xie, R. Xia, Z. Chen, J. Tian, L. Yan, M. Ren, Z. Li, G. Zhang, Q. Xue and H.-L. Yip, *Nano Energy*, 2020, **78**, 105238.
125. H. Aqoma, I. F. Imran, F. T. A. Wibowo, N. V. Krishna, W. Lee, A. K. Sarker, D. Y. Ryu and S. Y. Jang, *Adv. Energy Mater.*, 2020, **10**, 2001188.
126. K. Lang, Q. Guo, Z. He, Y. Bai, J. Yao, M. Wakeel, M. S. Alhodaly, T. Hayat and Z. a. Tan, *J. Phys. Chem. Lett.*, 2020, **11**, 9596-9604.
127. L. Liu, Z. Xiao, C. Zuo and L. Ding, *Journal of Semiconductors*, 2021, **42**, 020501.
128. X. Wu, Y. Liu, F. Qi, F. Lin, H. Fu, K. Jiang, S. Wu, L. Bi, D. Wang and F. Xu, *J. Mater. Chem. A*, 2021, **9**, 19778-19787.
129. P. Wang, W. Li, O. J. Sandberg, C. Guo, R. Sun, H. Wang, D. Li, H. Zhang, S. Cheng and D. Liu, *Nano Lett.*, 2021, **21**, 7845-7854.
130. W. Chen, D. Li, X. Chen, H. Chen, S. Liu, H. Yang, X. Li, Y. Shen, X. Ou and Y. Yang, *Adv. Funct. Mater.*, 2022, **32**, 2109321.
131. X. Gu, X. Lai, Y. Zhang, T. Wang, W. L. Tan, C. R. McNeill, Q. Liu, P. Sonar, F. He and W. Li, *Adv. Sci.*, 2022, **9**, 2200445.
132. Y. Ding, Q. Guo, Y. Geng, Z. Dai, Z. Wang, Z. Chen, Q. Guo, Z. Zheng, Y. Li and E. Zhou, *Nano Today*, 2022, **46**, 101586.
133. Y. Bai, Z. Zhou, Q. Xue, C. Liu, N. Li, H. Tang, J. Zhang, X. Xia, J. Zhang and X. Lu, *Adv. Mater.*, 2022, **34**, 2110587.
134. H. Yang, W. Chen, Y. Yu, Y. Shen, H. Yang, X. Li, B. Zhang, H. Chen, Q. Cheng and Z. Zhang, *Adv. Mater.*, 2023, **35**, 2208604.
135. Q. Yao, Y. M. Xie, Y. Zhou, Q. Xue, X. Xu, Y. Gao, T. Niu, L. Chu, Z. Zhou and F. R. Lin, *Adv. Funct. Mater.*, 2023, **33**, 2212599.
136. S. Q. Sun, X. Xu, Q. Sun, Q. Yao, Y. Cai, X. Y. Li, Y. L. Xu, W. He, M. Zhu and X. Lv, *Adv. Energy Mater.*, 2023, **13**, 2204347.
137. X. Lai, S. Chen, X. Gu, H. Lai, Y. Wang, Y. Zhu, H. Wang, J. Qu, A. K. K. Kyaw and H. Xia, *Nat. Commun.*, 2023, **14**, 3571.
138. S. S. Mali, J. V. Patil, J. A. Steele, M. K. Nazeeruddin, J. H. Kim and C. K. Hong, *Energy Environ. Sci.*, 2024, **17**, 1046-1060.
139. J. Huang, Z. Chen, Y. Zhang, J. Wang, W. Cai, J. Liu, Q. Meng, D. Luo, Y. Min and L. YUAN, 2024.
140. X. Y. Li, Z. Wu, Q. Yao, L. Y. Chen, W. Zeng, Q. Sun, F. R. Lin, A. K. Y. Jen, T. Shi and H. L. Yip, *Small*, 2025, **21**, 2406824.
141. J. Tian, C. Liu, K. Forberich, A. Barabash, Z. Xie, S. Qiu, J. Byun, Z. Peng, K. Zhang and T. Du, *Nat. Commun.*, 2025, **16**, 154.
142. G. Xie, H. Li, J. Fang, X. Wang, H. Peng, D. Lin, N. Huang, L. Gan, W. Li and R. Jiang, *Angew. Chem. Int. Ed.*, 2025, **64**, e202501764.
143. K. Lang, J. Xu, H. Han, H. Liu, Y. Fu, X. Zhang, Z. Sun, Q. Shi, Z. a. Tan and J. Yao, *Adv. Funct. Mater.*, 2025, 2502966.
144. S. Jiang, Z. Wang, C. Xu, J. Yang, Y. Wang, K. Gong, K. Li, T. Liu and Z. a. Tan, *Small*,

2025, 2500134.