Supporting Information for

Alkali Chloride Doped SnO_2 Electron-Transporting Layer for Boosting Charge Transfer and Passivating Defects in All-Inorganic $CsPbBr_3$ Perovskite Solar Cells

Guixiang Xie,[1] Xiaochun Lu,[1] Jialong Duan,[2,*] Yan Dong,[1] Xiurong Jiang,[1] Fengzhang Tu,[1] Yanyan Duan,[3] Qunwei Tang[1,2,*]

[1] College of Chemistry and Material Science, Longyan University, Longyan 364012, PR China;

[2] College of Information Science and Technology, Jinan University, Guangzhou 510632, PR China;

[3] State Centre for International Cooperation on Designer Low-Carbon and Environmental Material (SCICDLCEM), School of Materials Science and Engineering, Zhengzhou University, Zhengzhou 450001, PR China;

*Corresponding authors. E-mail addresses: duanjialong@jnu.edu.cn; tangqunwei@jnu.edu.cn.

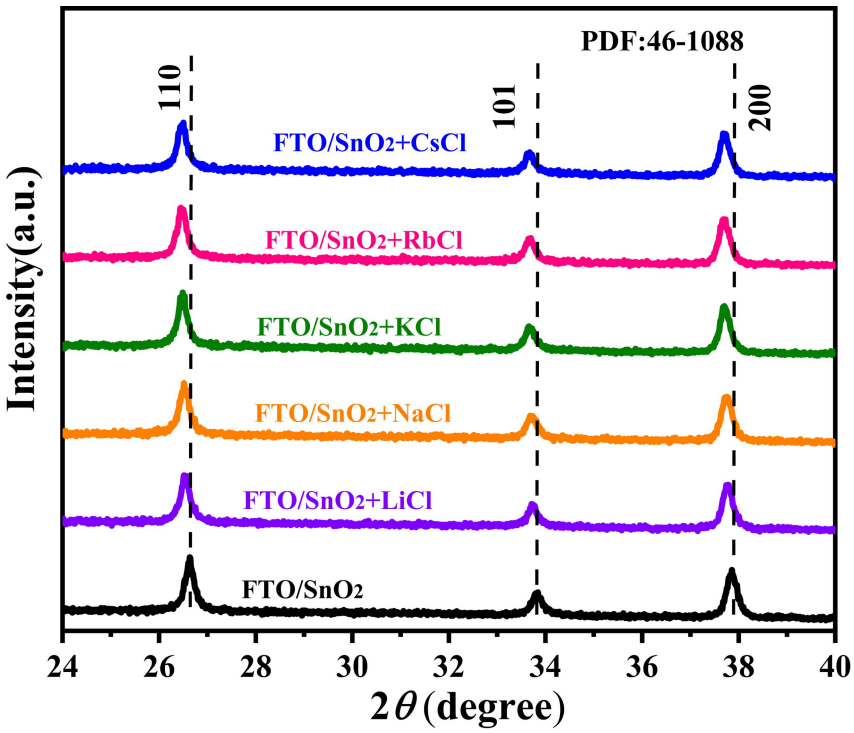

Figure S1. XRD patterns of SnO_2 and SnO_2-MCl (M = Li, Na, K, Rb and Cs) ETLs.

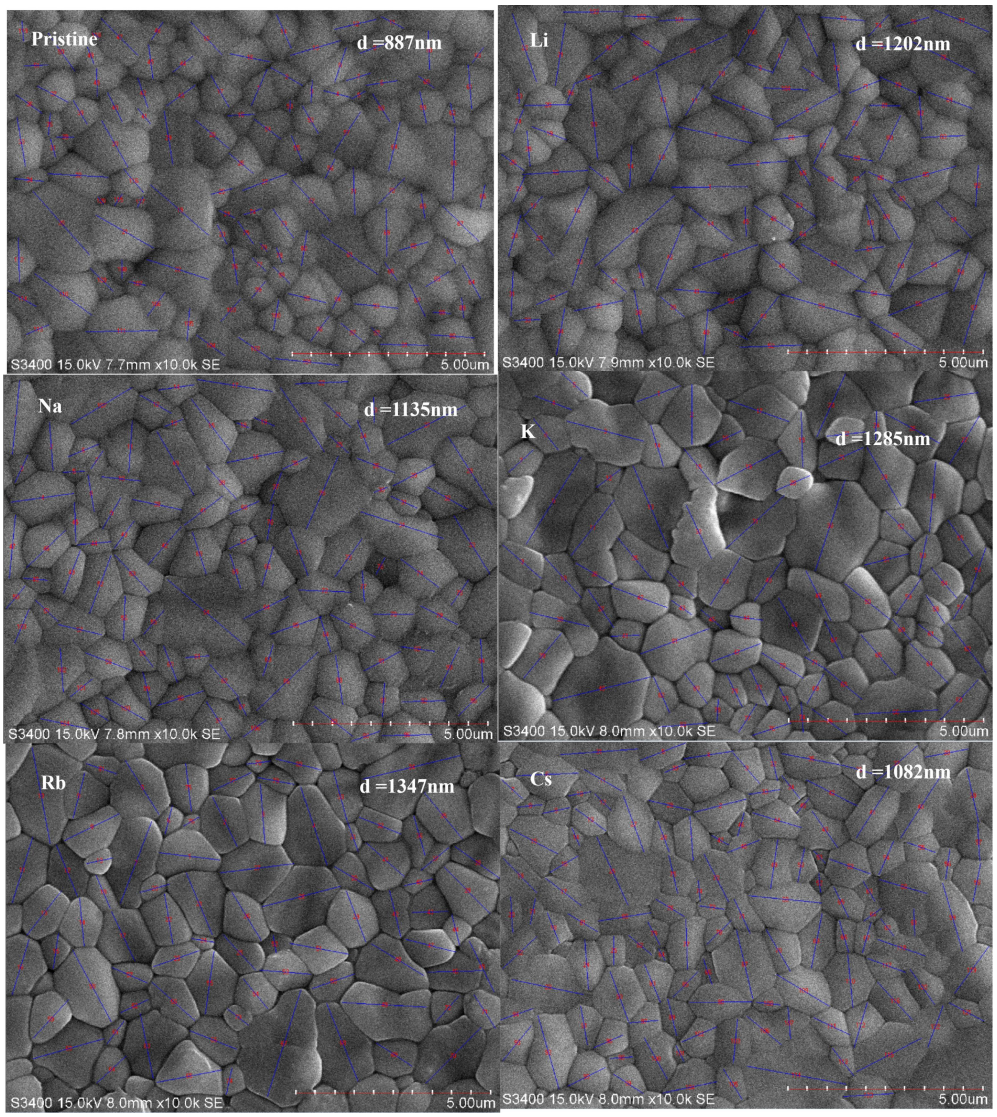

Figure S2. Grain size distributions of perovskite films based on SnO_2 and SnO_2-MCl (M = Li, Na, K, Rb and Cs) ETLs.

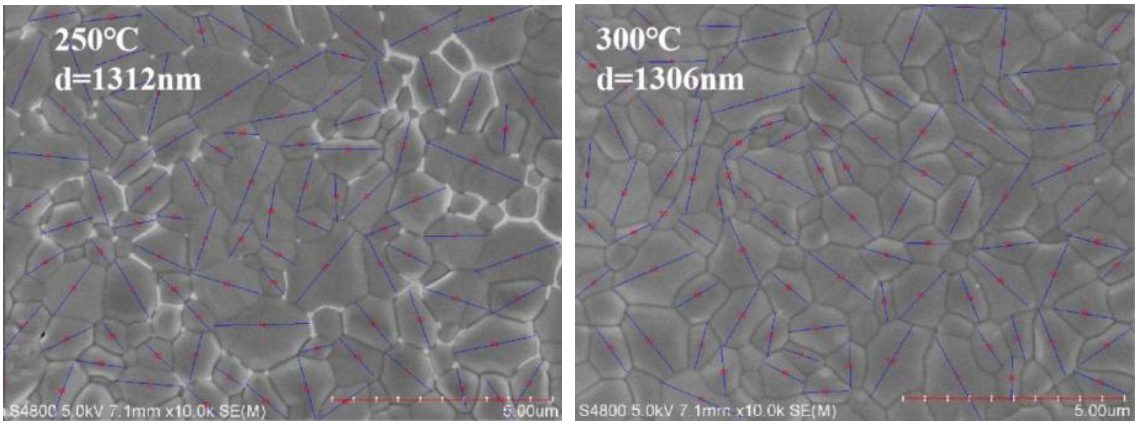

Figure S3. Grain size distributions of perovskite films on the surface of SnO_2-RbCl ETLs annealed at 250 °C (left) and 300 °C (right).

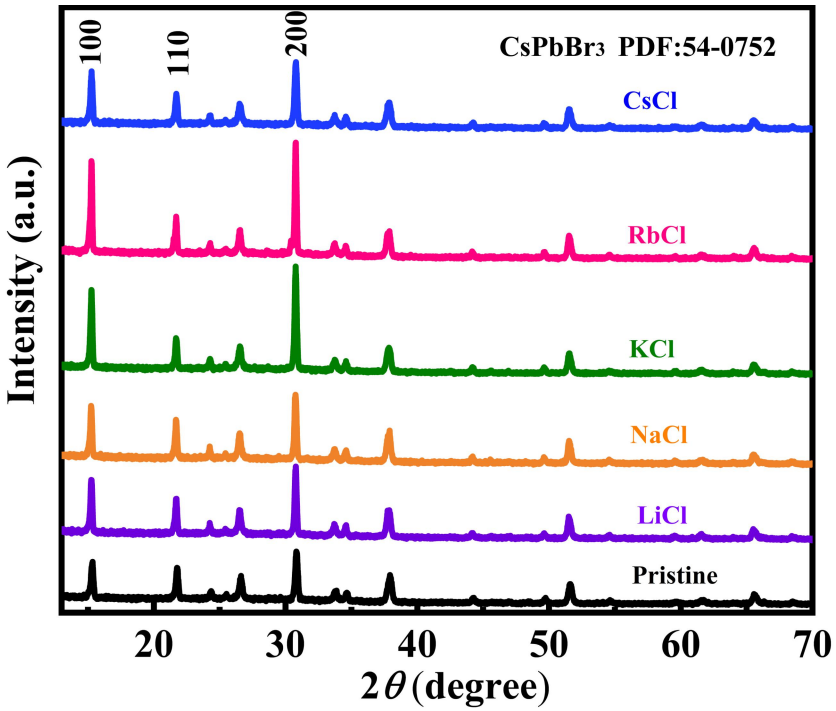

Figure S4. XRD patterns of $CsPbBr_3$ perovskite films based on SnO_2 and SnO_2-MCl (M = Li, Na, K, Rb and Cs) ETLs.

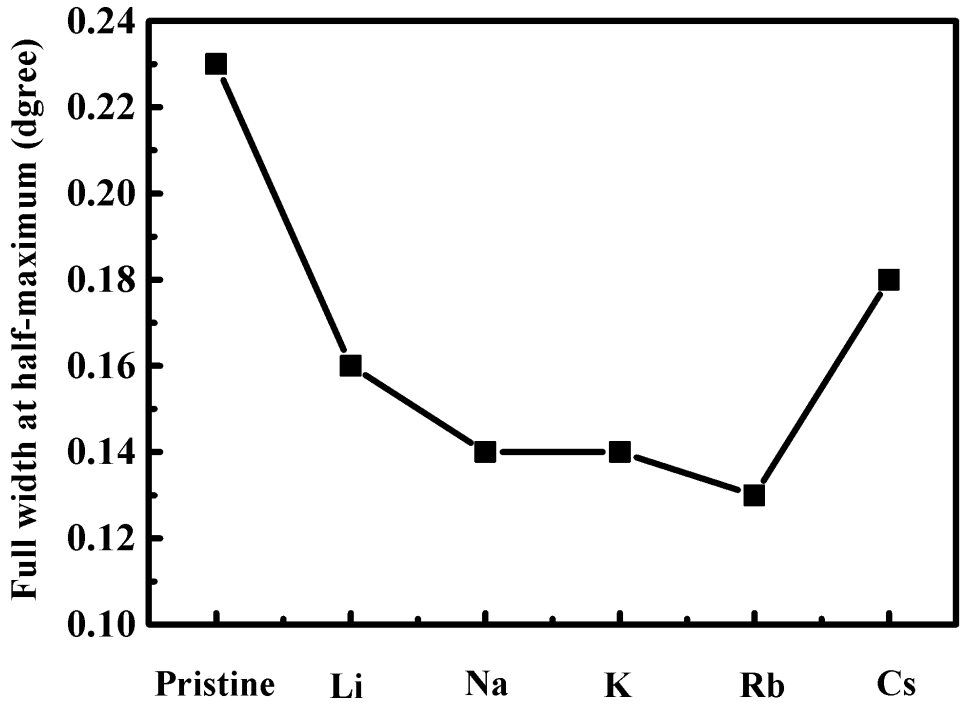

Figure S5. The full width at half-maximum evolution of (100) plane of $CsPbBr_3$ films obtained from Figure S4.

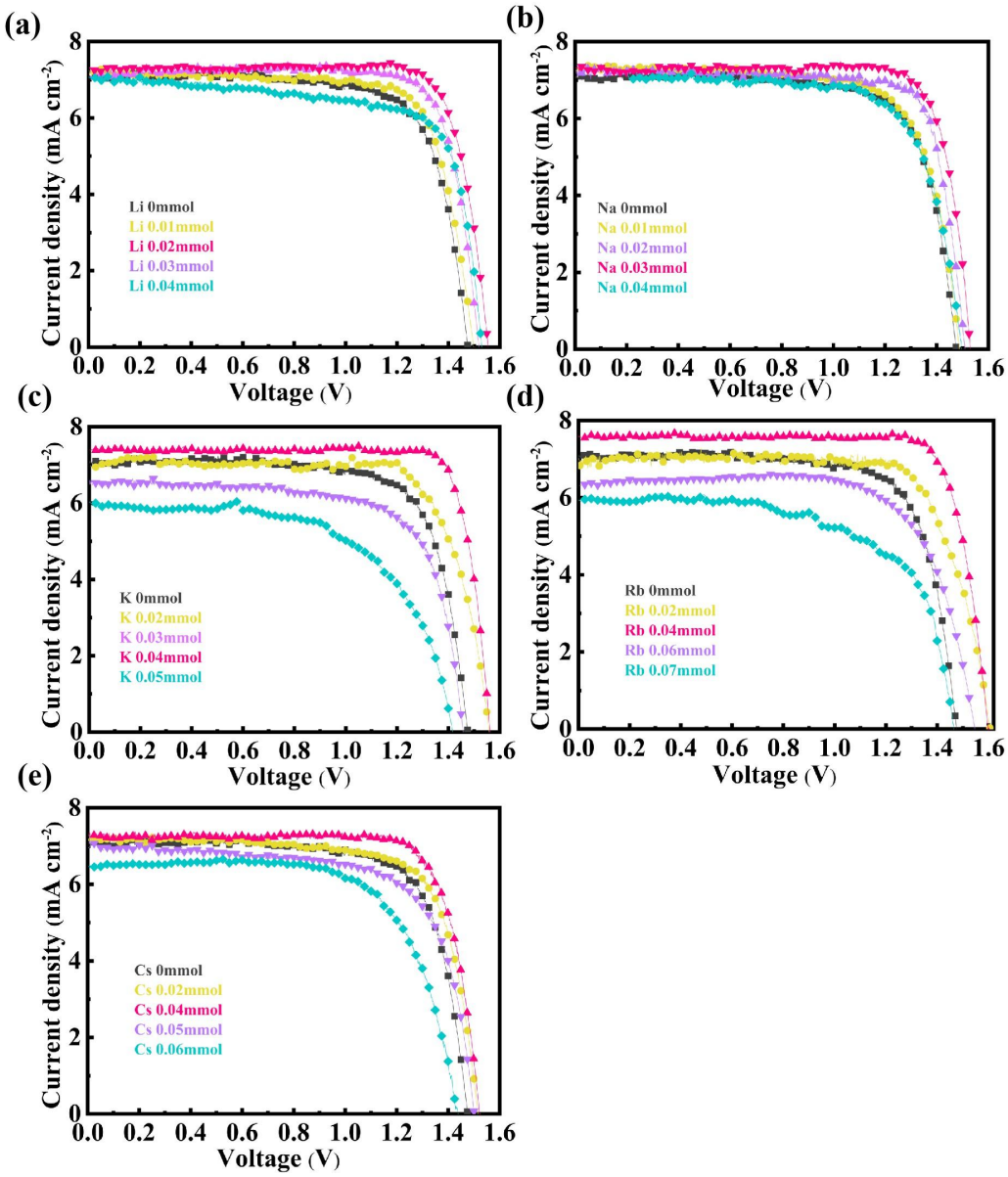

Figure S6. *J-V* curves of the inorganic PSCs with (a) SnO_2-LiCl**,** (b) SnO_2-NaCl, (c) SnO_2-KCl, (d) SnO_2-RbCl and (e) SnO_2-CsCl ETLs.

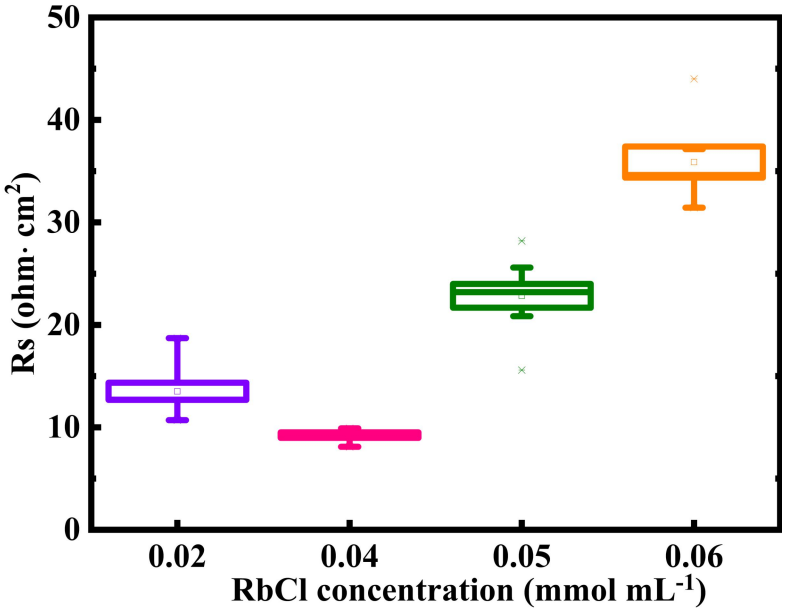

Figure S7. R_S values of PSCs at different RbCl concentrations.

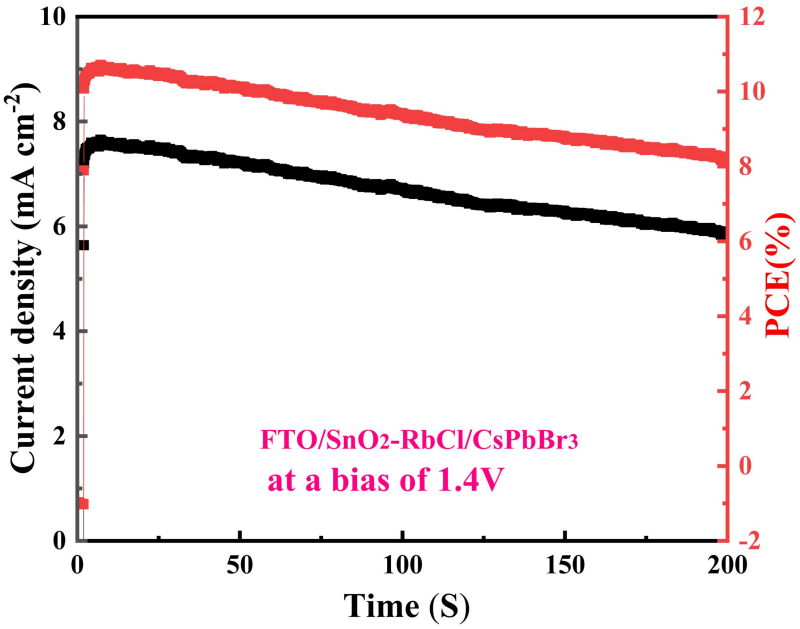

Figure S8. Steady-state power output at a maximum power point (bias voltage of 1.4 V) of SnO_2-RbCl ETL tailored $CsPbBr_3$ PSC.

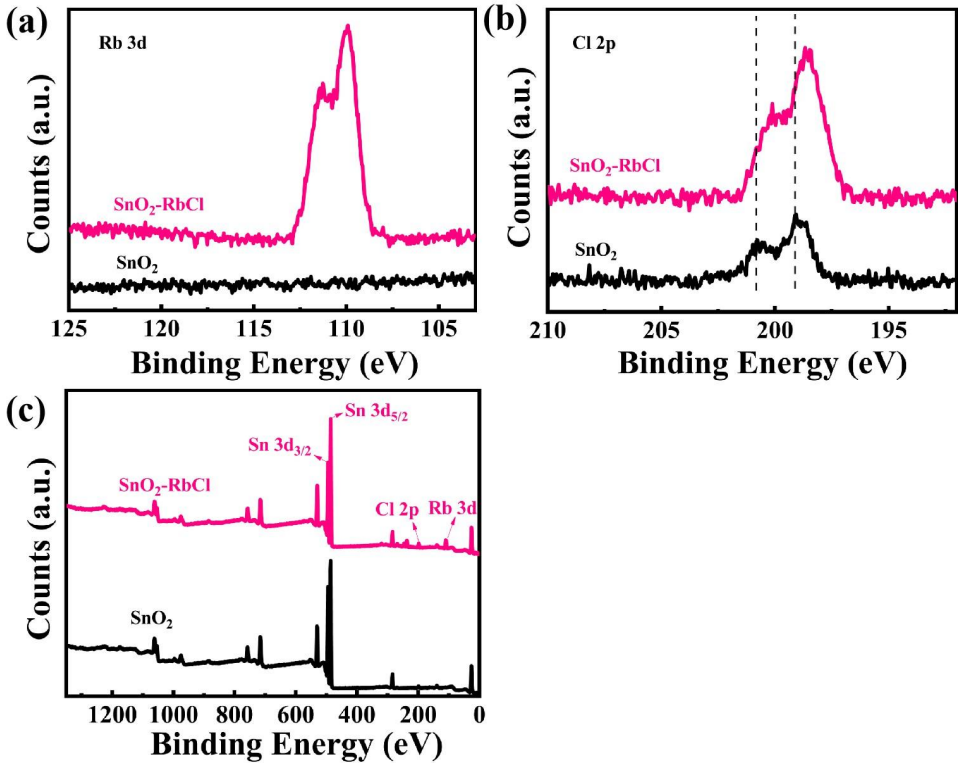

Figure S9. XPS spectra of (a) Rb 3d and (b) Cl 2p in SnO_2 and SnO_2-RbCl ETLs. (c) The whole XPS spectra of SnO_2 and SnO_2-RbCl films.

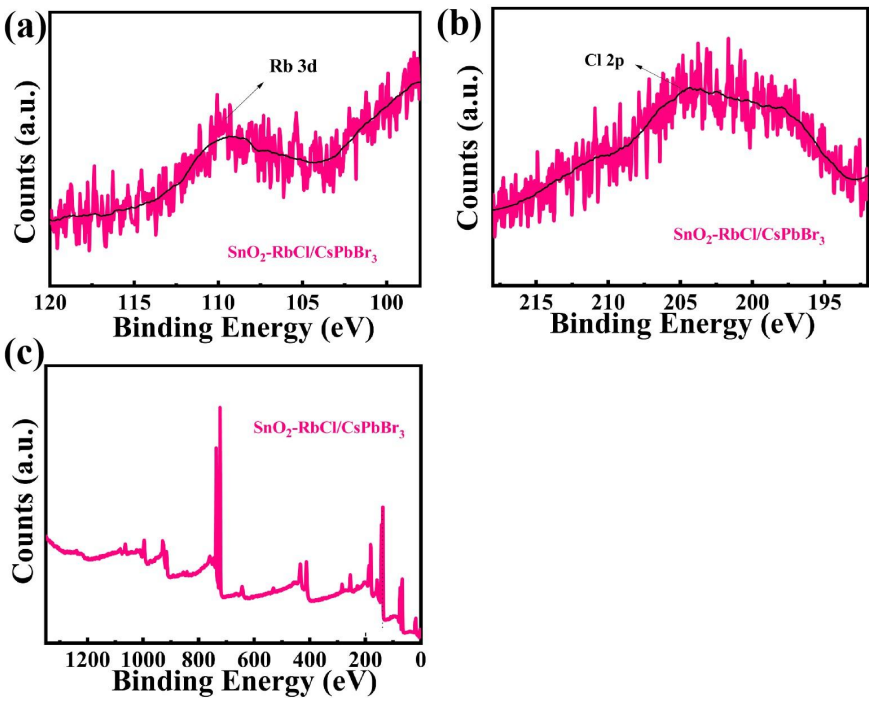

Figure S10. XPS spectra of perovskite film fabricated on SnO_2-RbCl ETL: (a) Rb 3d, (b) Cl 2p and (c) the whole spectrum.

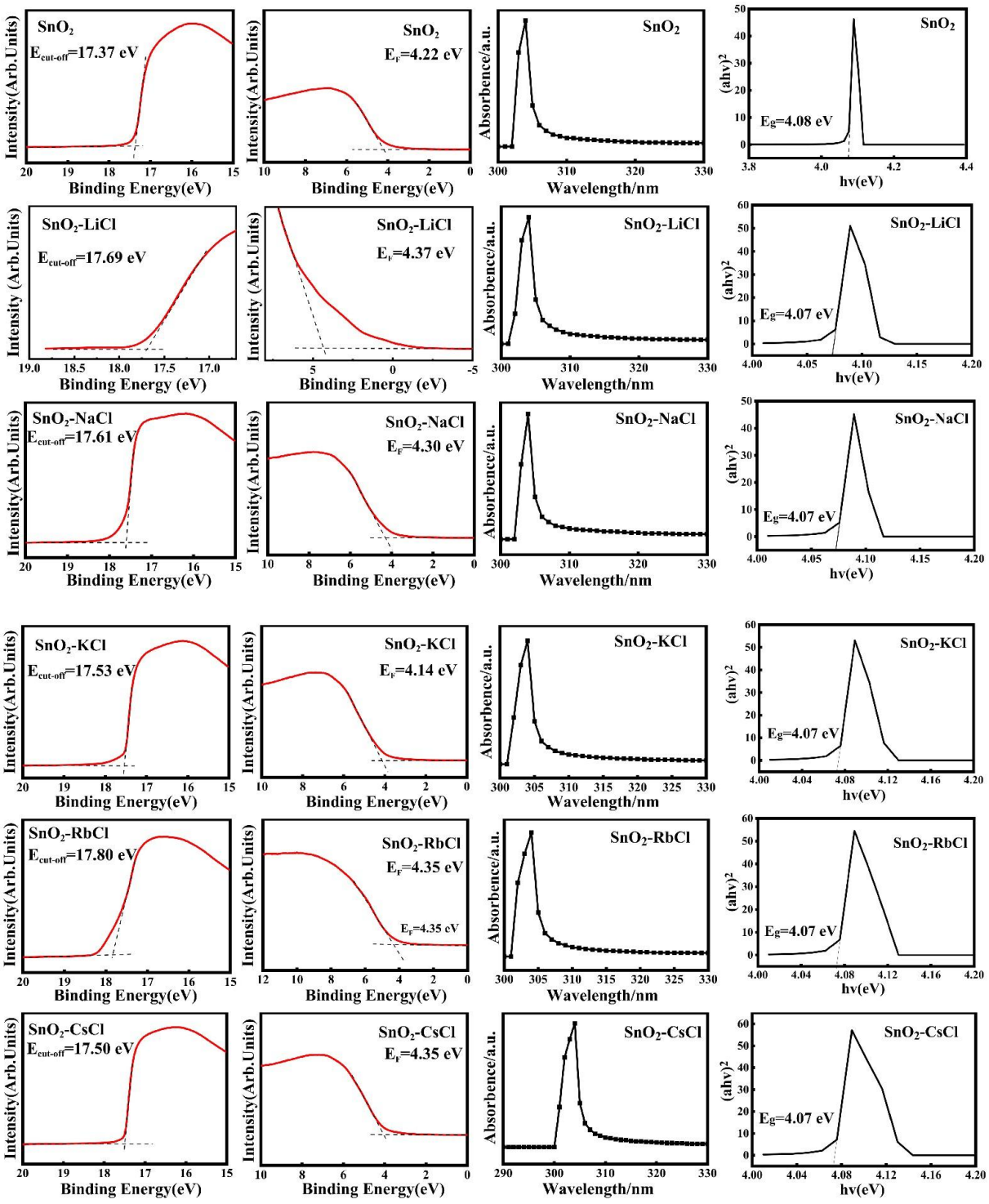

Figure S11. UPS spectra and UV-vis spectra of SnO_2 and SnO_2-MCl (M = Li, Na, K, Rb and Cs) ETLs.

Table S1. Comparison of photovoltaic parameters for state-of-the-art $CsPbBr_3$ PSCs.

Devices	V_{oc} (V)	J_{sc} (mA cm^{-2})	PCE (%)	*FF* (%)	Ref.
FTO/SnO_2-MCl/$CsPbBr_3$/Carbon	**1.601**	**7.69**	**10.04**	**81.6**	**This work**
FTO/*c*-TiO_2/*m*-TiO_2/$CsPbBr_3$/PTAA/Au	1.25	6.70	6.20	73.0	S[1]
FTO/*c*-TiO_2/*m*-TiO_2/$CsPbBr_3$/C	1.29	5.70	5.00	68.0	S[2]
FTO/ZnO/$CsPbBr_3$-$CsPb_2Br_5$/Spiro-OMeTAD/Au	1.43	6.17	6.81	77.2	S[3]
FTO/*c*-TiO_2/*m*-TiO_2/$CsPbBr_3$/Spiro-OMeTAD/Au	1.34	6.52	6.05	69.0	S[4]
ITO/ZnO/$CsPbBr_3$/Spiro-OMeTAD/Au	1.38	6.15	5.98	70.51	S[5]
FTO/TiO_2/CQD-$CsPbBr_3$ IO/Spiro-OMeTAD/Au	1.06	11.34	8.29	69.0	S[6]
FTO/SnO_2/$CsPbBr_3$/$CsSnBr_3$/Carbon	1.610	7.80	10.60	84.4	S[7]
FTO/Sb-TiO_2/$CsPbBr_3$/C	1.654	6.70	8.91	80.4	S[8]
FTO/*L*-TiO_2:$MoSe_2$/$CsPbBr_3$/C	1.615	7.88	10.02	78.7	S[9]
FTO/*c*-TiO_2/*m*-TiO_2/$CsPbBr_3$/C	1.24	7.4	6.7	73.0	S[10]
FTO/*c*-TiO_2/$CsPbBr_3$/C	1.34	6.46	5.86	68.04	S[11]
FTO/*m*-TiO_2/$CsPbBr_3$/PTAA/Au	1.27	6.16	5.72	73	S[12]
FTO/*c*-TiO_2/*m*-TiO_2/GQDs/$CsPbBr_3$/C	1.458	8.12	9.72	82.1	S[13]
FTO/*c*-TiO_2/*m*-TiO_2/Sm^{3+}-$CsPbBr_3$/C	1.594	7.48	10.14	85.1	S[14]
FTO/SnO_2/$CsPbBr_3$/N-CQDs/C	1.622	7.87	10.71	80.1	S[15]
FTO/*c*-TiO_2/*m*-TiO_2/Sm^{3+}-$CsPbBr_3$/Cu(Cr,Ba)O_2/C	1.615	7.81	10.79	85.5	S[16]
FTO/*c*-TiO_2/*m*-TiO_2/Sr^{2+}-$CsPbBr_3$/C	1.54	7.71	9.63	81.1	S[17]
FTO/*c*-TiO_2/*m*-TiO_2/GQDs/$CsPbBr_3$/MnS/C	1.52	8.28	10.45	83	S[18]
FTO/*c*-TiO_2/*m*-TiO_2/$CsPbBr_3$/Spiro-OMeTAD/Ag	1.37	6.41	6.32	72	S[19]
FTO/TiO_2/$CsPbBr_3$/C	1.19	7.48	6.12	68.8	S[20]
FTO/*c*-TiO_2/$CsPbBr_3$/C	1.49	6.89	8.11	79	S[21]
FTO/*c*-TiO_2/PTI-$CsPbBr_3$/spiro-OMeTAD/Ag	1.498	9.78	10.91	74.47	S[22]
FTO/*c*-TiO_2/*m*-TiO_2/GQDs/$CsPbBr_3$/P3HT/C	1.36	7.02	6.49	68	S[23]
FTO/*c*-TiO_2/SnO_2/$CsPbBr_3$/CuPc/C	1.31	8.24	8.79	81.4	S[24]
FTO/*c*-TiO_2/$CsPbBr_3$/C	1.545	7.37	9.35	82.2	S[25]
FTO/*c*-TiO_2/$CsPbBr_3$/Ti_3C_2-MXene/C	1.444	8.54	9.01	73.08	S[26]
FTO/*c*-TiO_2/*m*-TiO_2/Sn^{2+}-$CsPbBr_3$/C	1.37	7.66	8.63	82.22	S[27]
FTO/*c*-TiO_2/*m*-TiO_2/$CsPbBr_3$/C	1.22	7.40	7.37	84.1	S[28]
FTO/TiO_2/$CsPb_{0.998}Co_{0.002}Br_3$/Spiro-OMeTAD/Au	1.357	7.45	8.57	84.84	S[29]
FTO/*c*-TiO_2/$CsPbBr_3$/$CsPbBr_3$-$CsPb_2Br_5$/$CsPbBr_3$-Cs_4PbBr_6/C	1.461	9.26	10.17	75.39	S[30]

FTO/*c*-TiO_2/$CsPbBr_3$/spiro-OMeTAD/Au	1.27	6.97	6.95	78.5	S[31]
FTO/*c*-TiO_2/*m*-TiO_2/*m*-ZrO_2/$CsPbBr_3$/m-carbon	1.44	7.75	8.2	73.52	S[32]
FTO/*c*-TiO_2/$CsPbBr_3$–$CsPb_2Br_5$/spiro-OMeTAD/Ag	1.296	8.48	8.34	75.9	S[33]
FTO/*c*-TiO_2/$CsPbBr_3$/spiro-OMeTAD/Au	1.5	5.6	5.4	62	S[34]

Reference

[1] M. Kulbak, S. Gupta, N. Kedem, I. Levine, T. Bendikov, G. Hodes, D. Cahen, *J. Phys. Chem. Lett.* **2016**, *7*, 167–172.

[2] X. Chang, W. Li, L. Zhu, H. Liu, H. Geng, S. Xiang, J. Liu, H. Chen, *ACS Appl. Mater. Interfaces* **2016**, *8*, 33649–33655.

[3] X. Zhang, Z. Jin, J. Zhang, D. Bai, H. Bian, K. Wang, J. Sun, Q. Wang, S. F. Liu, *ACS Appl. Mater. Interfaces* **2018**, *10*, 7145–7154.

[4] K. C. Tang, P. You, F. Yan, *Sol. RRL* **2018**, *2*, 1800075.

[5] W. Chen, J. Zhang, G. Xu, R. Xue, Y. Li, Y. Zhou, J. Hou, Y. Li, *Adv. Mater.* **2018**, *30*, 1800855.

[6] S. Zhou, R. Tang, L. Yin, *Adv. Mater.* **2017**, *29*, 1703682.

[7] Y. Zhao, J. Duan, H. Yuan, Y. Wang, X. Yang, B. He, Q. Tang, *Sol. RRL* **2019**, 1800284.

[8] Y. Xu, J. Duan, X. Yang, J. Du, Y. Wang, Y. Duan, Q. Tang, *J. Mater. Chem. A* **2020**, *8*, 11859–11866.

[9] Q. Zhou, J. Du, J. Duan, Y. Wang, X. Yang, Y. Duan, Q. Tang, *J. Mater. Chem. A* **2020**, *8*, 7784–7791.

[10] J. Liang, C. Wang, Y. Wang, Z. Xu, Z. Lu, Y. Ma, H. Zhu, Y. Hu, C. Xiao, X. Yi, G. Zhu, H. Lv, L. Ma, T. Chen, Z. Tie, Z. Jin, J. Liu, *J. Am. Chem. Soc.* **2016**, *138*, 15829–15832.

[11] P. Teng, X. Han, J. Li, Y. Xu, L. Kang, Y. Wang, Y. Yang, T. Yu, *ACS Appl. Mater. Interfaces* **2018**, *10*, 9541–9546.

[12] M. Kulbak, D. Cahen, G. Hodes, *J. Phys. Chem. Lett.* **2015**, *6*, 2452–2456.

[13] J. Duan, Y. Zhao, B. He, Q. Tang, *Angew. Chem. Int. Ed.* **2018**, *57*, 3787–3791.

[14] J. Duan, Y. Zhao, X. Yang, Y. Wang, B. He, Q. Tang, *Adv. Energy Mater.* **2018**, *8*, 1802346.

[15] Y. Zhao, J. Duan, Y. Wang, X. Yang, Q. Tang, *Nano Energy* **2020**, *67*, 104286.

[16] J. Duan, Y. Zhao, Y. Wang, X. Yang, Q. Tang, *Angew. Chem. Int. Ed.* **2019**, *58*, 16147–16151.

[17] Y. Zhao, Y. Wang, J. Duan, X. Yang, Q. Tang, *J. Mater. Chem. A* **2019**, *7*, 6877–6882.

[18] X. Li, Y. Tan, H. Lai, S. Li, Y. Chen, S. Li, P. Xu, J. Yang, *ACS Appl. Mater. Interfaces* **2019**, *11*, 29746–29752.

[19] H. Wang, Y. Wu, M. Ma, S. Dong, Q. Li, J. Du, H. Zhang, Q. Xu, *ACS Appl. Energy Mater.* **2019**, *2*, 2305–2312.

[20] X. Cao, G. Zhang, L. Jiang, Y. Cai, Y. Gao, W. Yang, X. He, Q. Zeng, G. Xing, Y. Jia, J. Wei, *ACS Appl. Mater. Interfaces* **2019**, *12*, 5925–5931.

[21] X. Wan, Z. Yu, W. Tian, F. Huang, S. Jin, X. Yang, Y.-B. Cheng, A. Hagfeldt, L. Sun, *J. Energy Chem.* **2020**,

46, 8–15.

[22] G. Tong, T. Chen, H. Li, L. Qiu, Z. Liu, Y. Dang, W. Song, L. K. Ono, Y. Jiang, Y. Qi, *Nano Energy* **2019**, *65*, 104015.

[23] G. Wang, W. Dong, A. Gurung, K. Chen, F. Wu, Q. He, R. Pathak, Q. Qiao, *J. Power Sources* **2019**, *432*, 48–54.

[24] X. Liu, X. Tan, Z. Liu, H. Ye, B. Sun, T. Shi, Z. Tang, G. Liao, *Nano Energy* **2019**, *56*, 184–195.

[25] T. Xiang, Y. Zhang, H. Wu, J. Li, L. Yang, K. Wang, J. Xia, Z. Deng, J. Xiao, W. Li, Z. Ku, F. Huang, J. Zhong, Y. Peng, Y.-B. Cheng, *Sol. Energy Mater. Sol. Cells* **2019**, 110317.

[26] T. Chen, G. Tong, E. Xu, H. Li, P. Li, Z. Zhu, J. Tang, Y. Qi, Y. Jiang, *J. Mater. Chem. A* **2019**, *7*, 20597–20603.

[27] H. Guo, Y. Pei, J. Zhang, C. Cai, K. Zhou, Y. Zhu, *J. Mater. Chem. C* **2019**, *7*, 11234–11243.

[28] D. Huang, P. Xie, Z. Pan, H. Rao, X. Zhong, *J. Mater. Chem. A* **2019**, *7*, 22420–22428.

[29] D. Wang, W. Li, Z. Du, G. Li, W. Sun, J. Wu, Z. Lan, *J. Mater. Chem. C* **2020**, *8*, 1649–1655.

[30] G. Tong, T. Chen, H. Li, W. Song, Y. Chang, J. Liu, L. Yu, J. Xu, Y. Qi, Y. Jiang, *Sol. RRL* **2019**, *3*, 1900030.

[31] J. Lei, F. Gao, H. Wang, J. Li, J. Jiang, X. Wu, R. Gao, Z. Yang, S. (Frank) Liu, *Sol. Energy Mater. Sol. Cells* **2018**, *187*, 1–8.

[32] I. Poli, J. Baker, J. McGettrick, F. De Rossi, S. Eslava, T. Watson, P. J. Cameron, *J. Mater. Chem. A* **2018**, *6*, 18677–18686.

[33] H. Li, G. Tong, T. Chen, H. Zhu, G. Li, Y. Chang, L. Wang, Y. Jiang, *J. Mater. Chem. A* **2018**, *6*, 14255–14261.

[34] Q. A. Akkerman, M. Gandini, F. Di Stasio, P. Rastogi, F. Palazon, G. Bertoni, J. M. Ball, M. Prato, A. Petrozza, L. Manna, *Nat. Energy* **2017**, *2*, 16194.