Support information

Boosting performance of perovskite solar cells through a novel active passivation method

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This file includes Table S1 and Figure S1-S5.

Table S1 Full width at half maximum (FWHM) of (110) and (220) peak.

	2θ(110)	**FWHM**	**2θ(220)**	**FWHM**
Ref 14 min	14.175	0.086	28.463	0.095
KCl 7 min	14.158	0.078	28.457	0.100
KCl 14 min	14.167	0.079	28.462	0.090
KCl 20 min	14.219	0.152	28.520	0.183

As displayed in Table S1, the FWHM of (110) and (220) peak of KCl-based perovskite film with 14 min thermal annealing is smaller than that of pristine $MAPbI_{3-x}Cl_x$ film. It is consistent with the phenomenon that the crystallite size increased in the case of KCl pretreatment observed in SEM images.

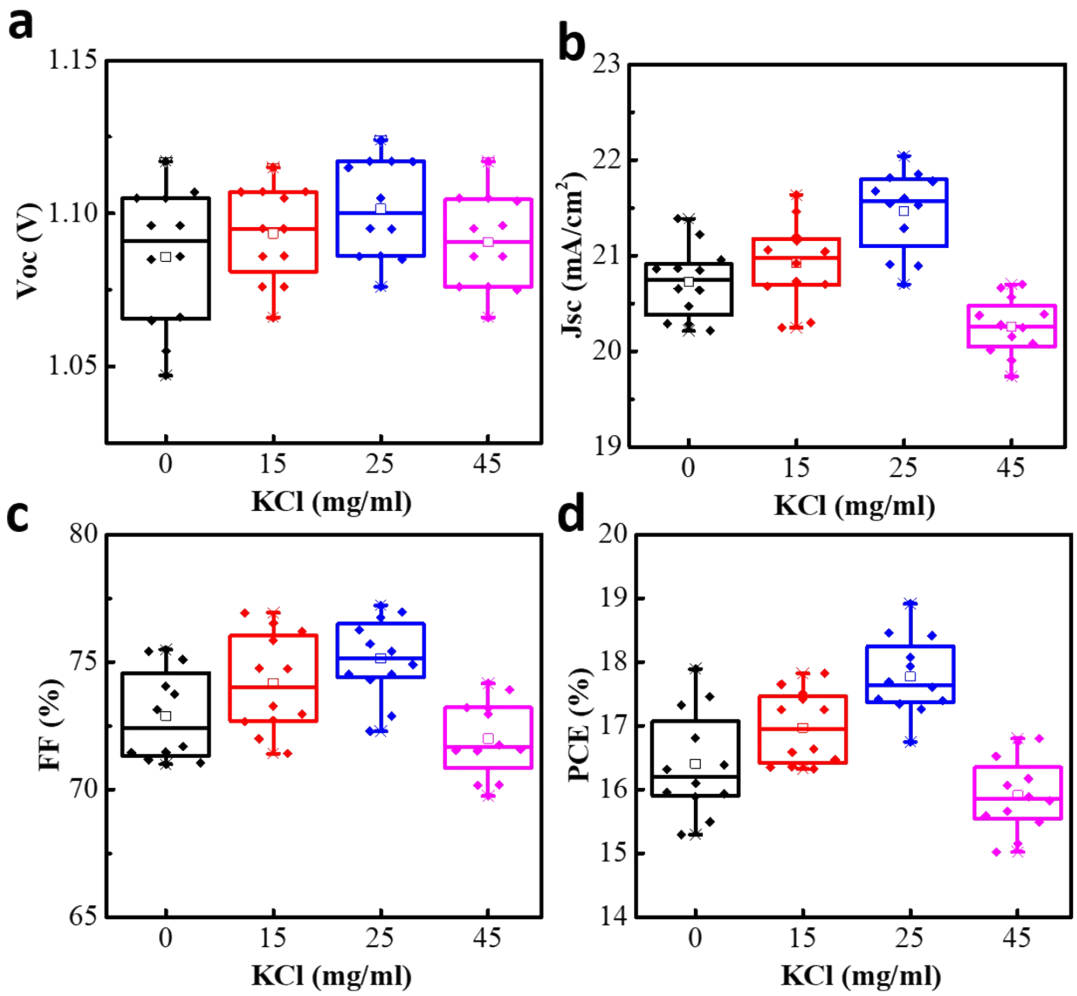

Figure S1 Photovoltaic performances statistics of PSCs teated with KCl solution of different concentrations.

Firstly, the KCl solution concentration is believed to have large impact on the device performance. As shown in Fig. S1, the proper concentration of KCl is 25 mg/ml. For the PSCs with a 15 mg/ml KCl solution treatment, both of J_{sc} and V_{oc} is enhanced compared to the pristine $MAPbI_{3-x}Cl_x$-based PSCs, results in an obvious increase of PCE. However, when the concentration of KCl solution reached 45 mg/ml, the inserted KCl layer was too thick to be absorbed completely by perovskite film during thermal annealing.

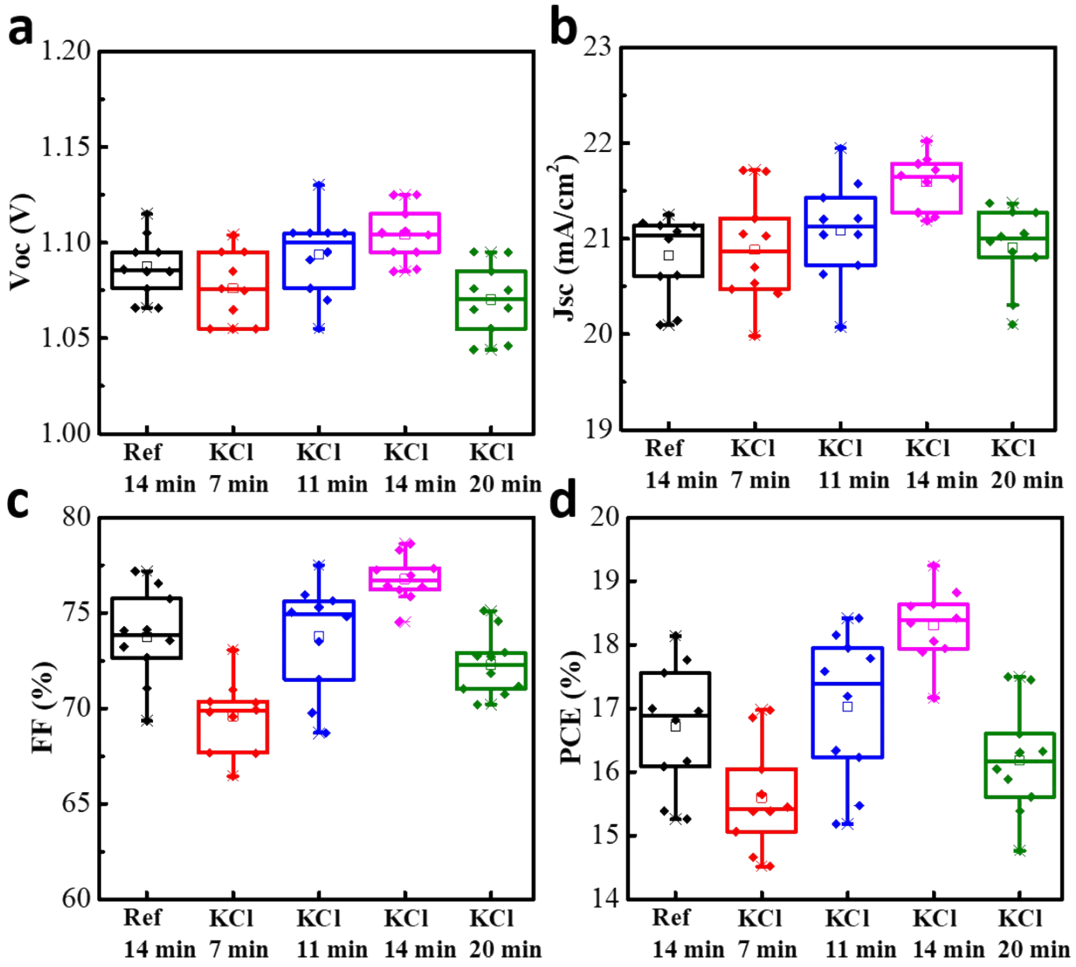

Figure S2 Photovoltaic performances statistics of KCl-based PSCs with different annealing time.

Meanwhile, the annealing time of perovskite film is regarded as another critical parameter of the fabrication. As shown in Fig. S2, the most suitable annealing time for KCl-based PSCs is 14 min.

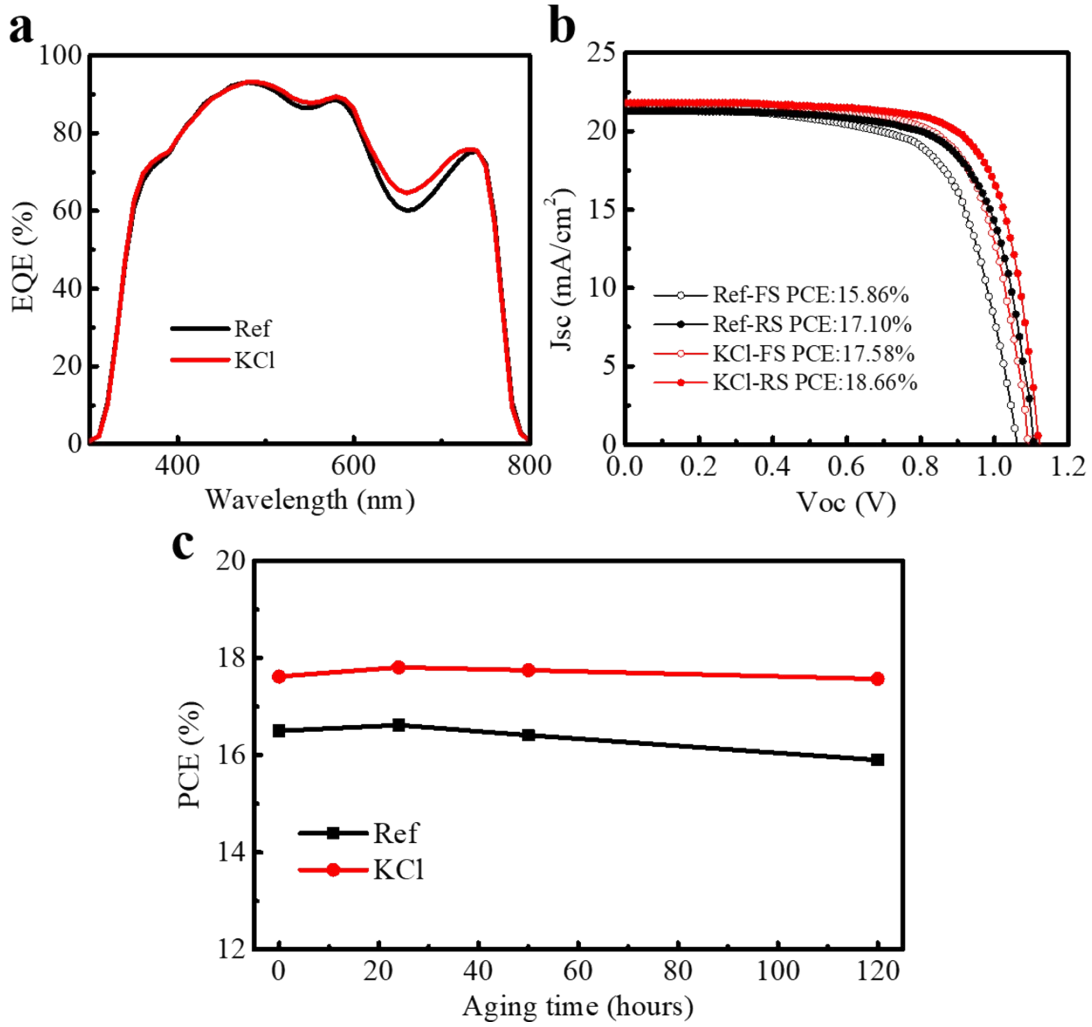

Figure S3 (a) EQE spectra of PSC with and without KCl pretreatment. (b) The J-V curve of pristine $MAPbI_{3-x}Cl_x$ PSC (15.86% for forward scan (FS), 17.10% for reverse scan (RS)) and KCl-based PSC(17.58% for forward scan, 18.66% for reverse scan). (c) Long-term stabilities of of PSCs with and without KCl pretreatment stored in glovebox without encapsulation.

As presented in Fig. S3a, the EQE spectra well matches with the enhancement of current density in the case of KCl pretreatment. The J-V curves of PSCs with and without KCl pretreatment were recorded in Fig. S3b. It should be noted that I-V hysteresis of PSCs was decreased by KCl pretreatment, where it could be ascribed to the reduction of trap states density. Comparison of the stability of KCl treated devices and pristine $MAPbI_{3-x}Cl_x$-based devices is given in Fig. S3c. The KCl treated PSCs are more stable than pristine $MAPbI_{3-x}Cl_x$-based PSCs.

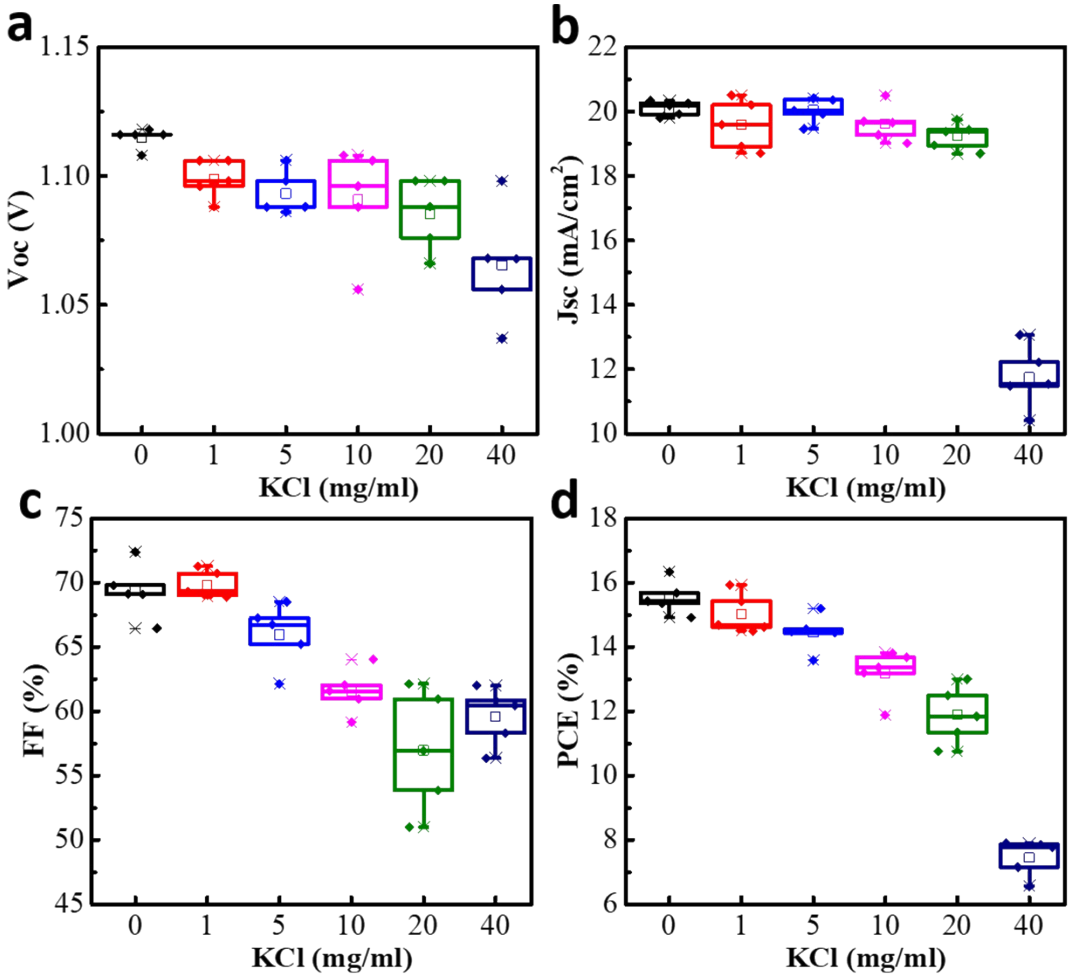

Figure S4 Photovoltaic performances statistics of PSCs wit5h SnO_2 layer prepared with mixed SnO_2:KCl (4:x mg/ml, x = 0, 1, 5, 10, 20 and 40) solution.

Apart from being absorbed by perovskite absorber, KCl may also diffuse into the electron transport layer (SnO_2 layer). For the result displayed in Fig. S4, the performance of PSCs with KCl doped SnO_2 did not enhanced, conforming that the performance enhancement of KCl based PSCs is due to the diffusion of KCl into perovskite rather than SnO_2.

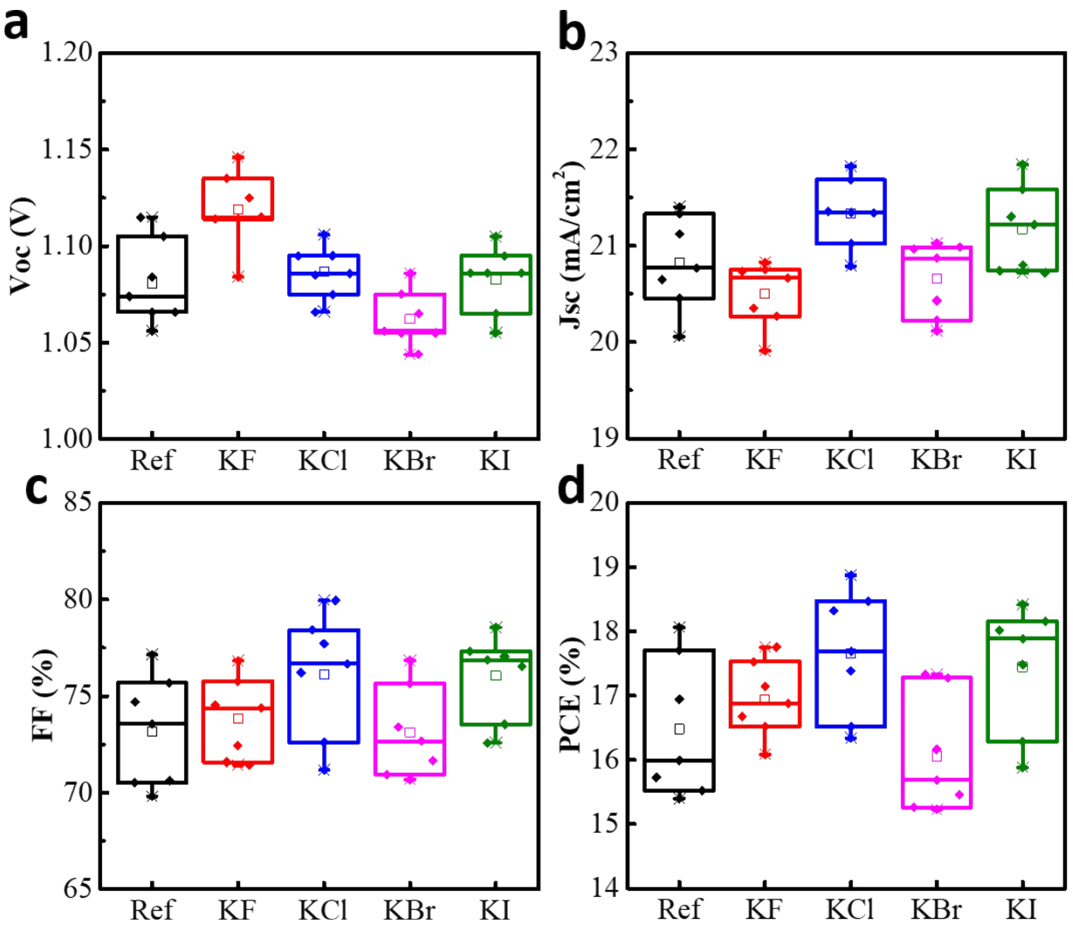

Figure S5 Photovoltaic performances statistics of PSCs treated with different potassium halides.

We replaced KCl with other potassium halides (KF, KBr, KI) to explore the effect of other potassium halides. The detailed statistic data of photovoltaic characteristics were plotted in Fig. S5. It is noteworthy that both KF and KI pretreatment could also improve device performance suggesting the similar diffusion process takes place at these two device as well. While KBr pretreatment did not show much improvement in device performance.