Supporting Information

# Attenuating the Defect Activities with Rubidium Additive for Efficient and Stable Sn-Based Halide Perovskite Solar Cells

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**Table and Figures**

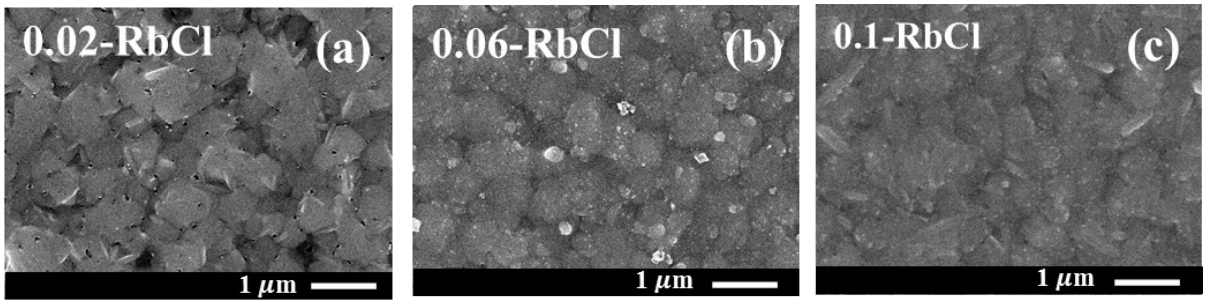


**Figure S1.** SEM images of $FASnI_3$ films with RbCl additive (a) 0.02, (b) 0.06, and (c) 0.1.

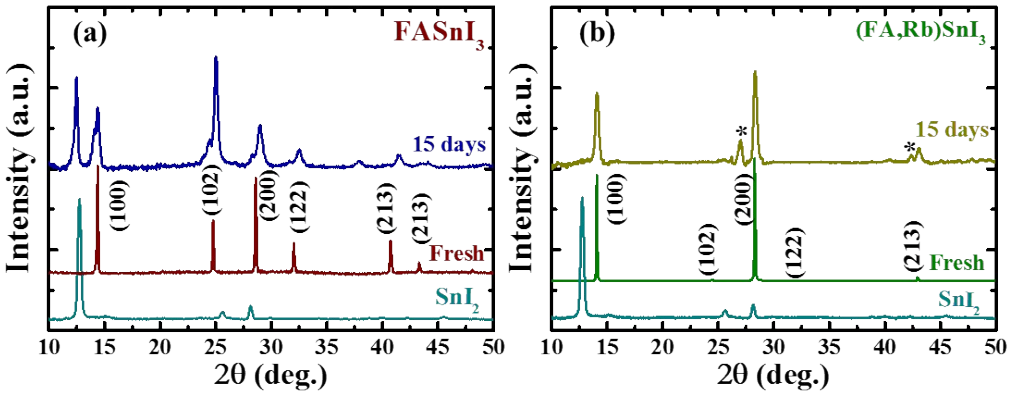


**Figure S2.** XRD patterns of PMMA coated $FASnI_3$ film with 0-RbCl (a) and 0.08-RbCl i.e. $(FA,Rb)SnI_3$ (b) for fresh film and after 15 days stored under nitrogen ambient in glovebox. The XRD pattern of $SnI_2$ with 10% $SnF_2$ also has been displayed to evaluate the film deterioration. The pure FASnI3 film decomposes to $SnI_2$ with aging indicating rather unstable than $FARbSnI_3$.

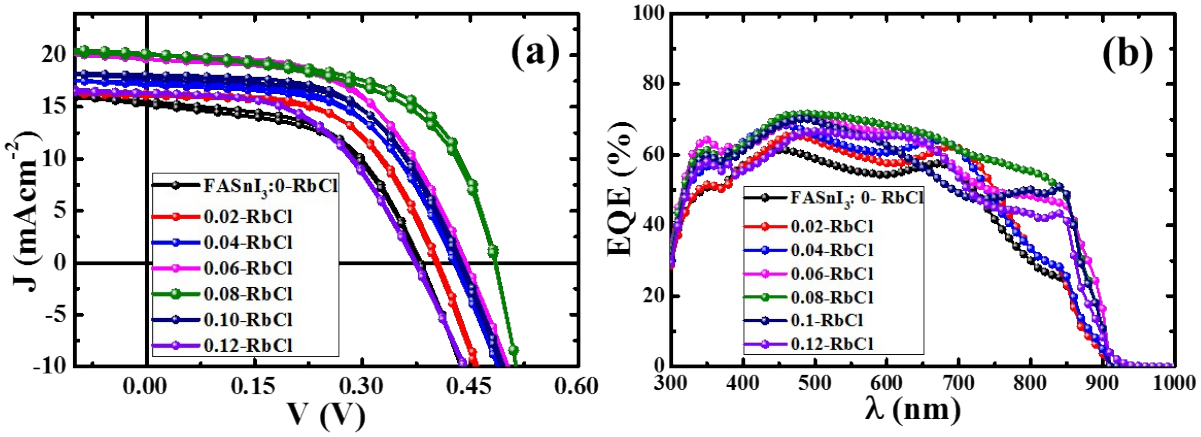


**Figure S3.** J-V curves (a) and EQE spectra (b) of the $FA_{1-x}Rb_xSnI_3$ devices with different RbCl content (x=0-0.12).

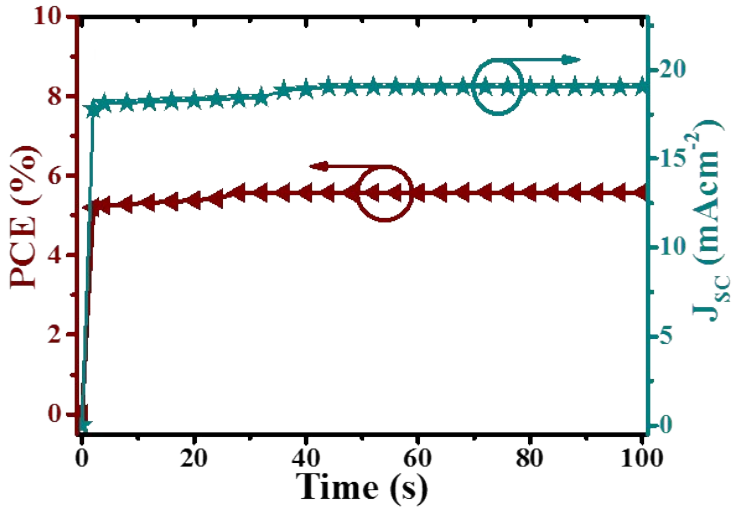


**Figure S4.** The steady state $J_{SC}$ and PCE of the encapsulated device ($FASnI_3$ with 0.08-RbCl) at 30 °C (~50% RH) under 1 sun measured under MPPT condition.

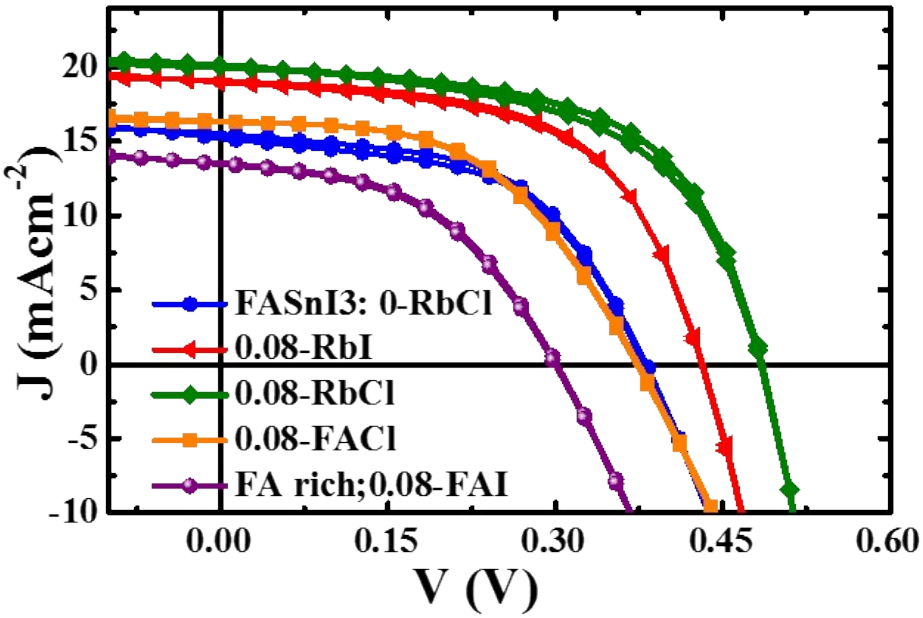


**Figure S5.** J-V characteristics of devices with $FASnI_3$ with different additives.

**Table ST1.** Device parameters of the respective devices.

| $FASnI_3$ with | 0-RbCl | 0.08-RbI | 0.08-RbCl | 0.08-FACl | FA rich: FAI-0.08% |
|---|---|---|---|---|---|
| Jsc (mA/cm2) | 15.52 | 19.10 | 20.04 | 14.37 | 13.53 |
| Voc (V) | 0.382 | 0.430 | 0.487 | 0.390 | 0.302 |
| FF | 0.54 | 0.581 | 0.604 | 0.568 | 0.482 |
| Rs (Ω·cm2) | 4.57 | 3.33 | 3.25 | 4.73 | 4.97 |
| Rsh (Ω·cm2) | 1.89E2 | 1.20E3 | 1.53E3 | 1.05E3 | 2.02E2 |
| $\eta$ (%) | 3.22 | 4.78 | 5.89 | 3.18 | 1.97 |

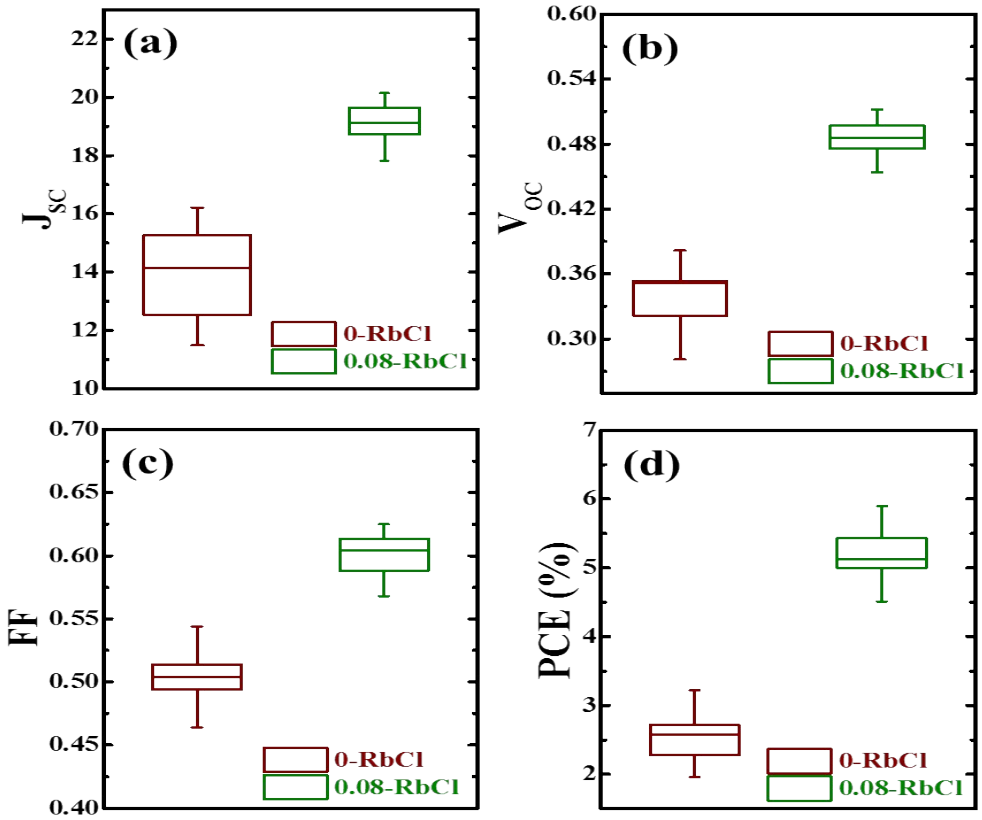


**Figure S6.** Statistics of device parameters for the devices with pristine $FASnI_3$ (0-RbCl) and 0.08-RbCl. Histogram of device parameters: (a) $J_{SC}$, (b) $V_{OC}$ ($\eta$), (c) *FF*, and (d) efficiency of 20 devices fabricated 4 different batches.

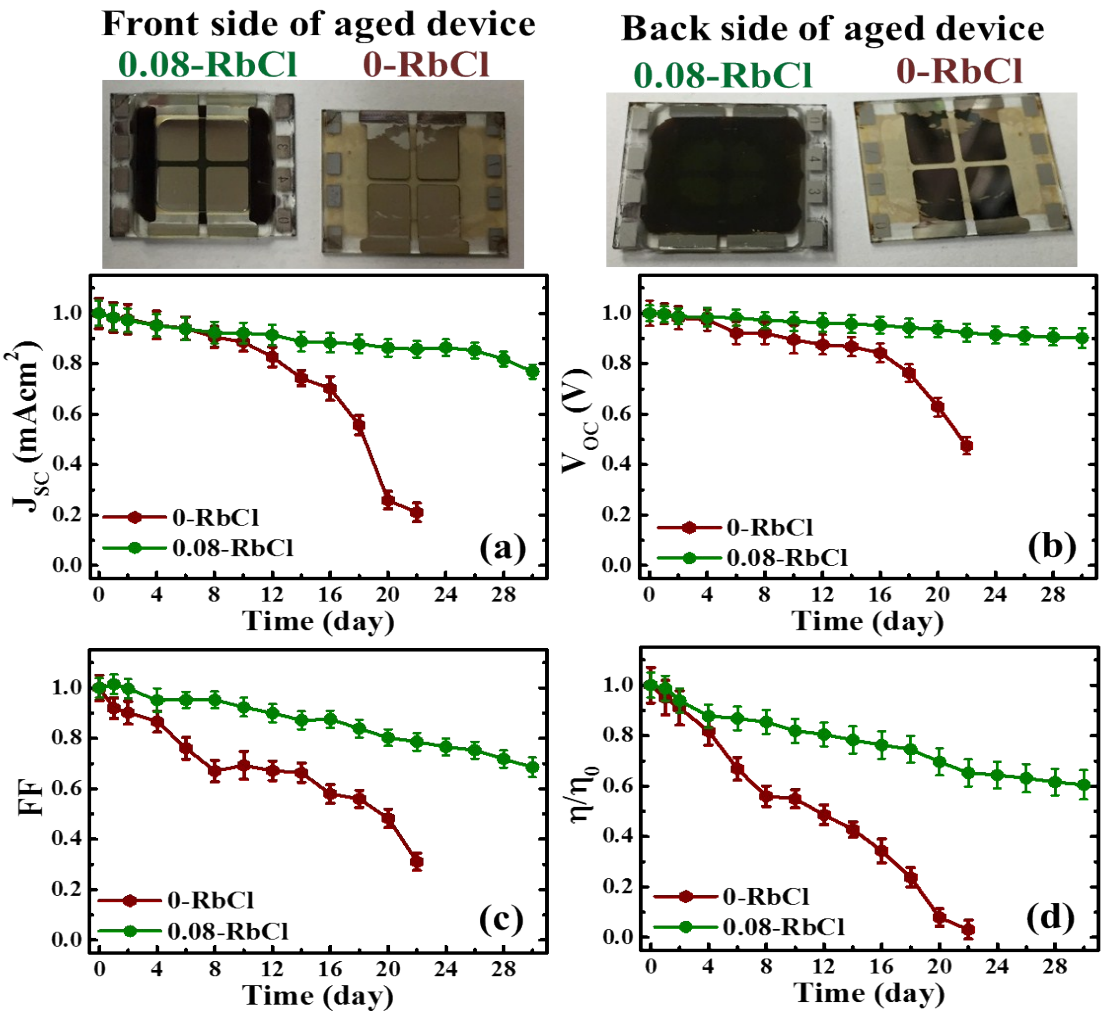


**Figure S7.** Stability data (solar cell parameter $J_{SC}$, $V_{OC}$, FF, and $\eta$) of encapsulated devices with pristine $FASnI_3$ (0-RbCl) and 0.08-RbCl stored under ambient conditions for 30 days. Note that the top images show the photos of aged devices with pristine $FASnI_3$ (0-RbCl) and 0.08-RbCl.

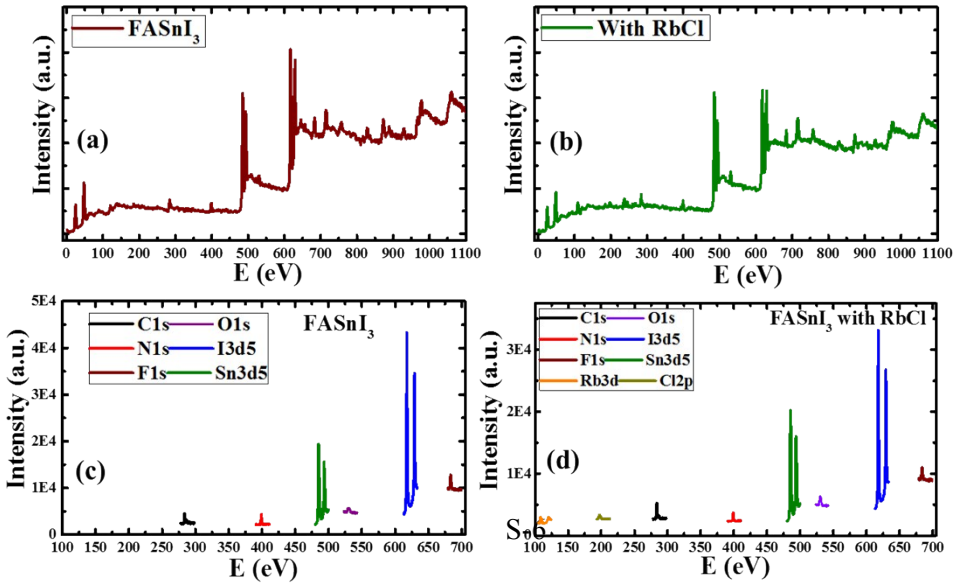

**Figure S8.** XPS spectra of $FASnI_3$ pristine (0-RbCl) (a, c) and with RbCl (b, d).

**Table ST2.** Summary of atomic percentage (atm %) of different elements on the surfaces of pristine $FASnI_3$ (0-RbCl) and with 0.08-RbCl additive, extracted from XPS analysis.

| Sample | C1s (atm %) | N1s (atm %) | O1s (atm %) | F1s (atm %) | Cl2p (atm %) | Rb3d (atm %) | Sn3d5 (atm %) | I3d5 (atm %) |
|---|---|---|---|---|---|---|---|---|
| Pristine $FASnI_3$ | 24.64 | 10.19 | 9.35 | 7.83 | - | - | 20.04 | 27.95 |
| | 25.04 | 12.34 | 8.41 | 7.62 | - | - | 19.58 | 27.01 |
| $FASnI_3$ With RbCl additive | 27.24 | 7.02 | 8.31 | 4.14 | 3.14 | 1.38 | 19.45 | 28.91 |
| | 27.05 | 6.09 | 9.2 | 4.92 | 2.34 | 1.47 | 19.64 | 29.19 |

**Table ST3.** The constituents stoichiometry of Sn, I, X (I + Cl + F), and Rb on the surfaces of respective films calculated from XPS analysis.

| Sample | Sn:I (1:~3) | Sn(1.1): X (3) (1:2.73) | Sn (1.1):Rb(0.08) (1:0.072) |
|---|---|---|---|
| $FASnI_3$ Pristine | 1.0: 1.39 | 1: 1.78 | - |
| | 1: 1.38 | 1: 1.77 | - |
| $FASnI_3$ With RbCl additive | 1: 1.49 | 1: 1.86 | 1: 0.0709 |
| | 1: 1.48 | 1: 1.85 | 1: 0.0748 |

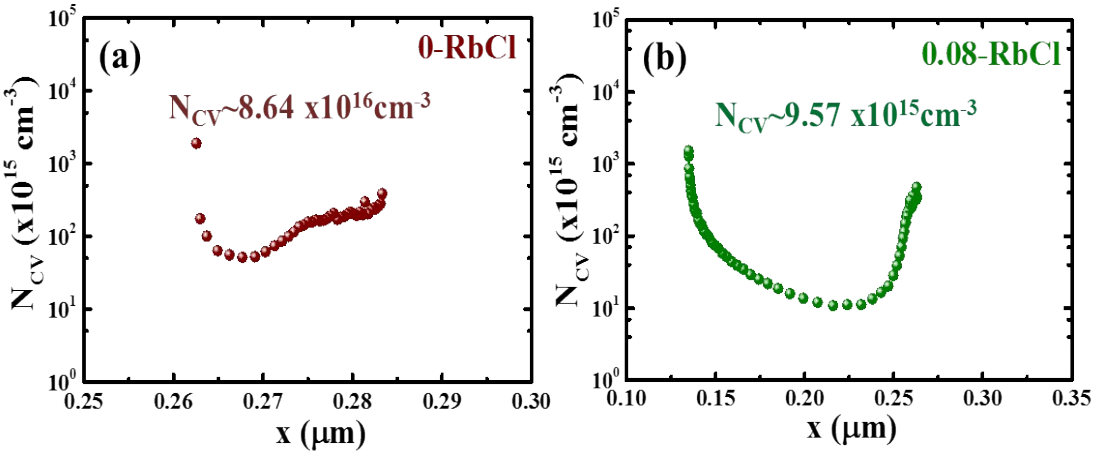


**Figure S9.** *C–V* analysis: Carrier profile for the $FASnI_3$ devices with out and with RbCl content.

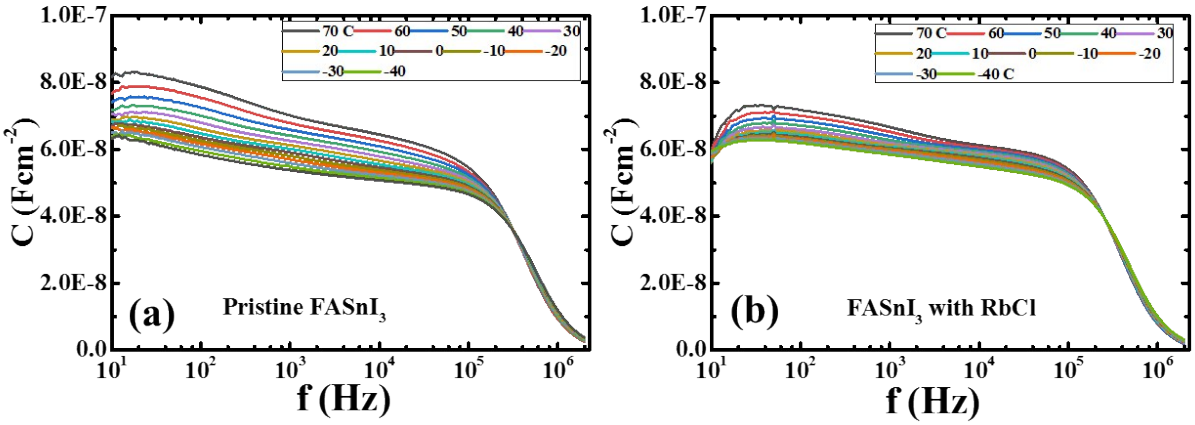


**Figure S10.** Capacitance- frequency (C-f) spectra of $FASnI_3$ devices without and with RbCl content.

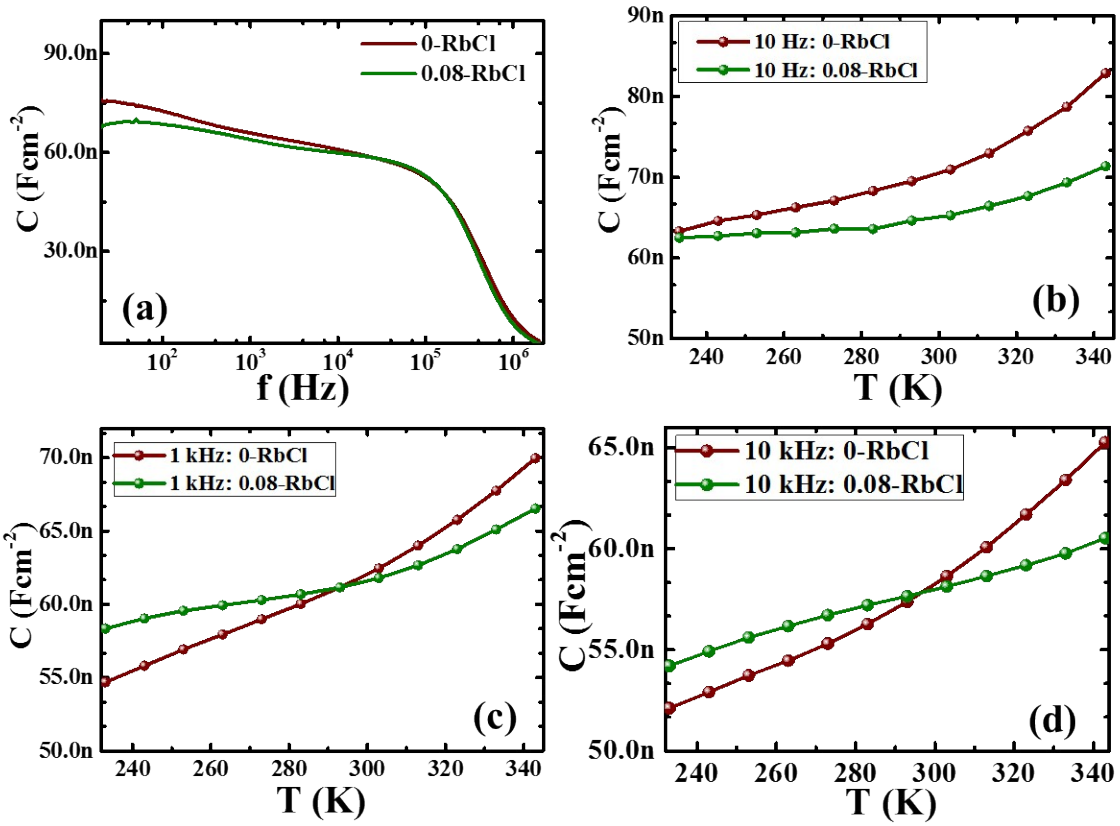


**Figure S11.** Capacitance response of $FASnI_3$ devices (0-RbCl and 0.08 RbCl). (a) C-f spectra at room temperature and capacitance response obtained at 10 Hz (b), 1 kHz (c), and 10 kHz with varying temperatures (230 to 350 K).