Supplementary Materials

The Degradation and Recovery behaviors of Mix-cations Perovskite Solar Cells in Carbon Dioxide and Moisture Environment

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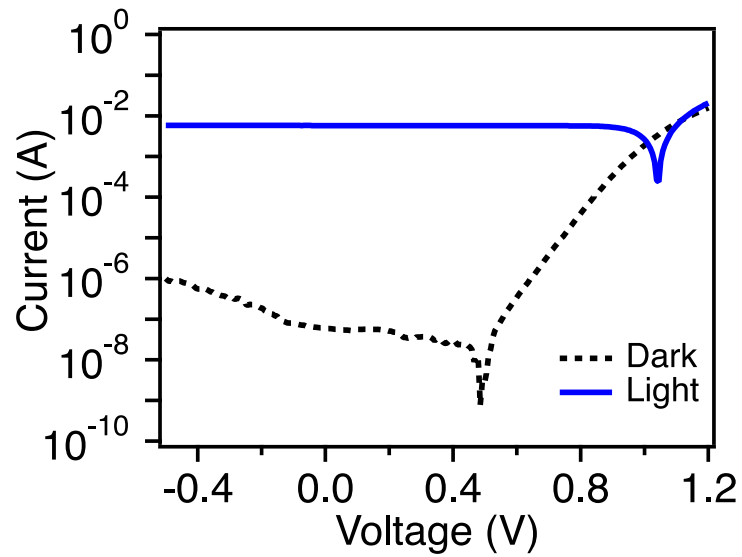*Correspondence: wanyi@lanl.gov

Supplementary Figures

Figure S1. On-off ratio from perovskites devices' *J-V* characteristic curves of dark and light.
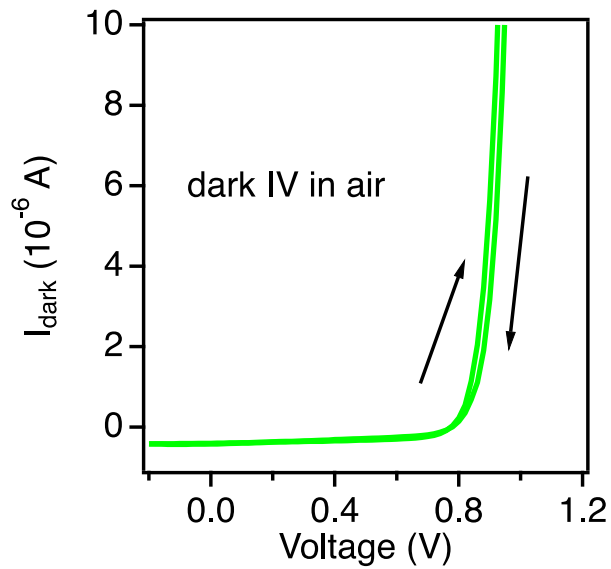

Figure S2. Hysteresis loop scan of dark IV curve for Au device collected under ambient environment.
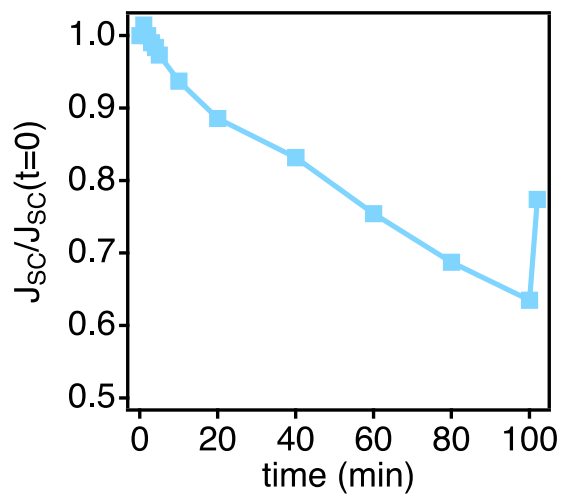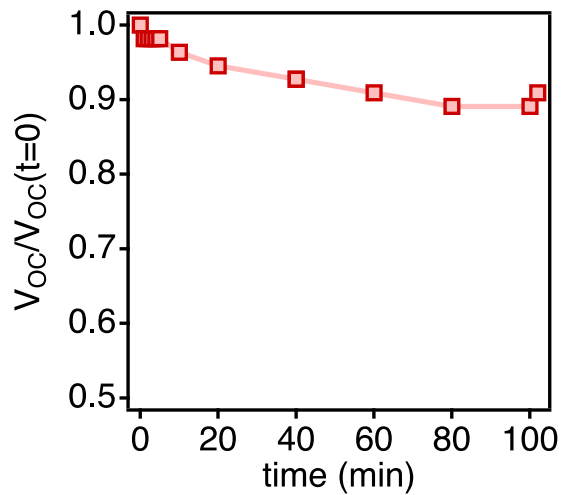
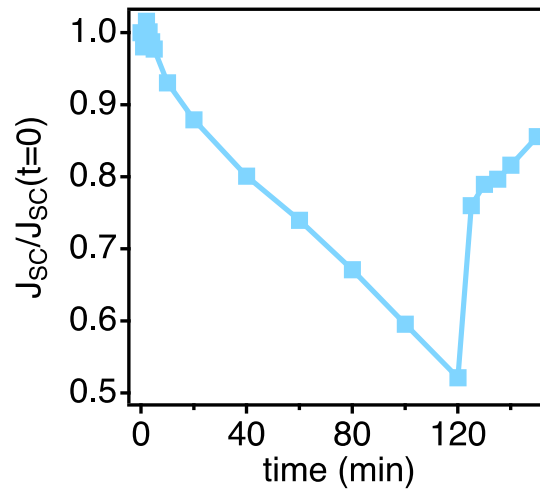**Figure S3.** Time evolution of (a) the normalized V_{OC} and (b) J_{SC} under dry nitrogen environment.
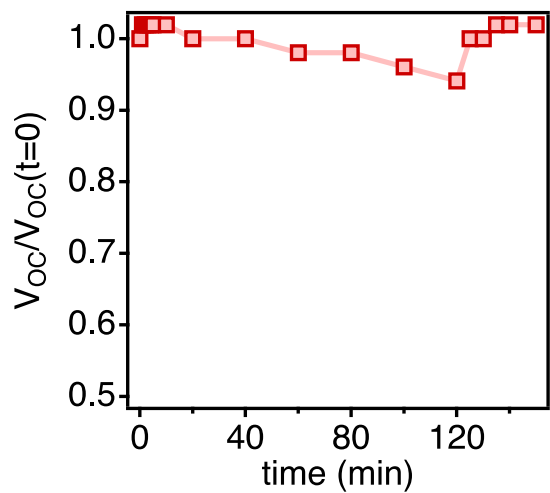

Figure S4. Time evolution of (a) the normalized V_{OC} and (b) J_{SC} for repeating CO_2 with RH=0%.
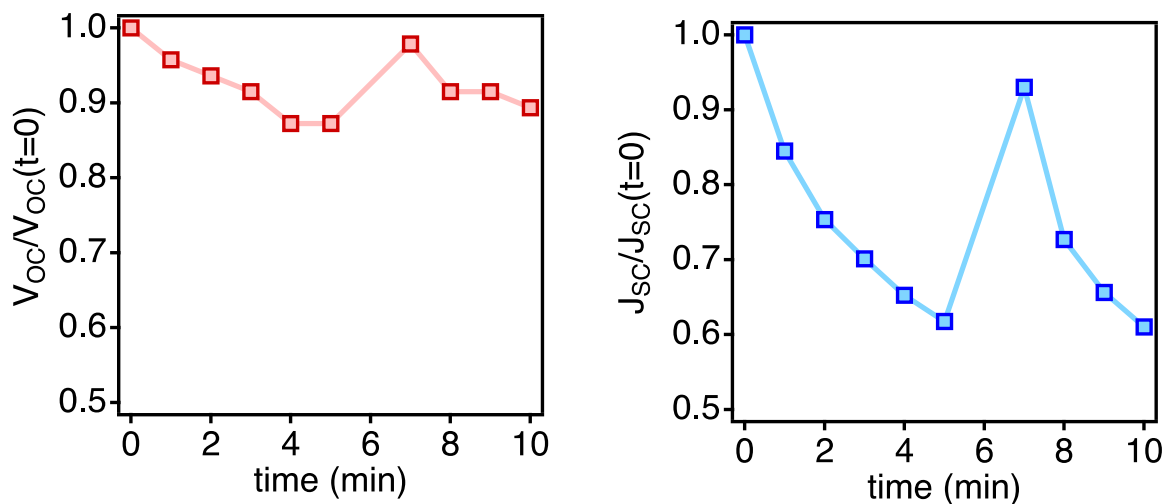
Figure S5. Time evolution of (a) the normalized V_{OC} and (b) J_{SC} under ambient environment (air, R.H. = 20 %).
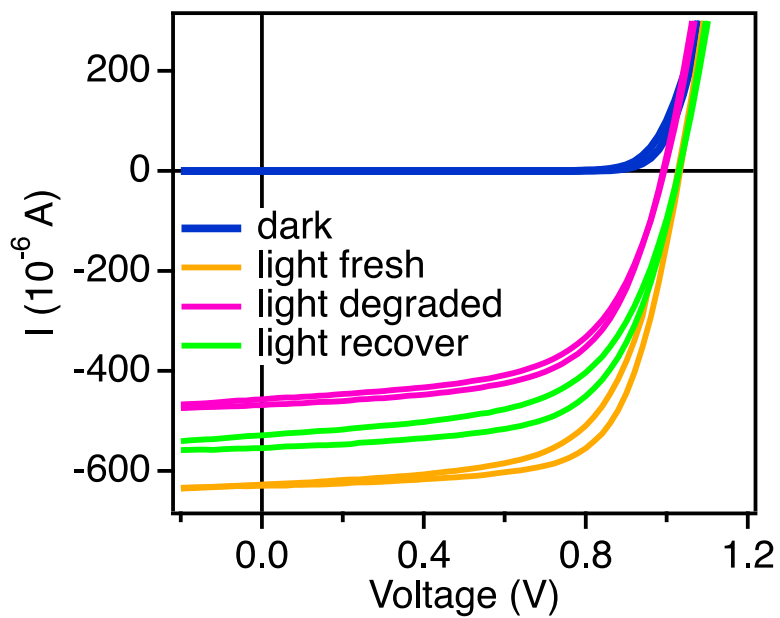

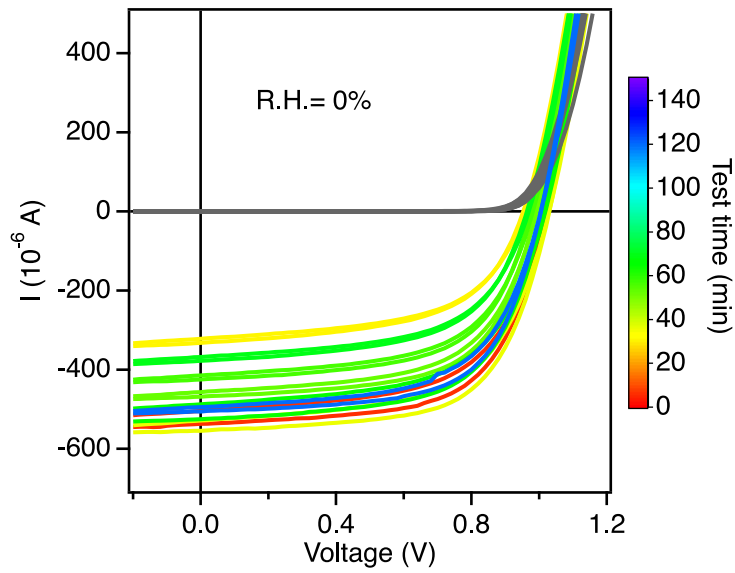**Figure S6.** Hysteresis loop scan with repeating light J-V curves for CO_2 with RH=0% at fresh, degraded and recovered status.

Figure S7. Hysteresis loop scan with repeating light *J-V* curves for CO_2 with RH=60% at various exposure time.
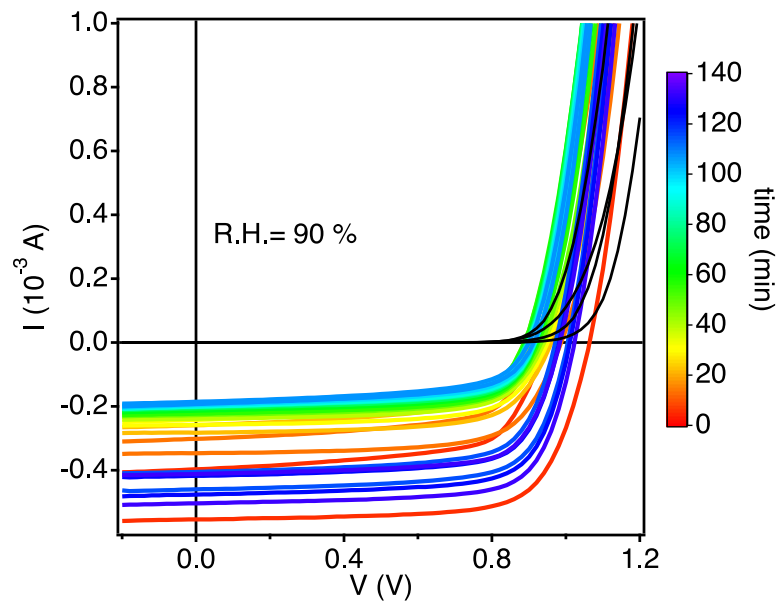

Figure S8. Hysteresis loop scan with repeating light *J-V* curves for CO_2 with RH=90% at various exposure time.
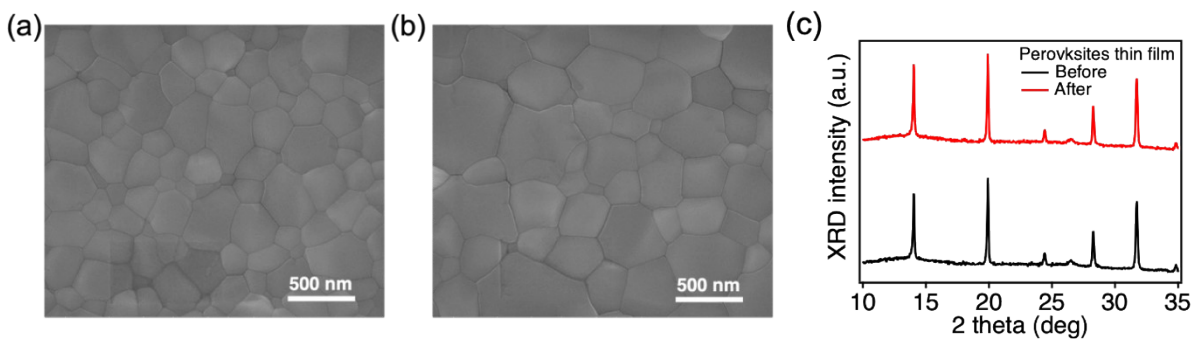
Figure S9. SEM surface views for perovskite thin film (a) before and (b) after the exposure in CO_2 with R.H.=90% environment for 2 hours under illumination. XRD patterns for the perovskites device before and after testing under CO_2 with R.H.=90% environment.
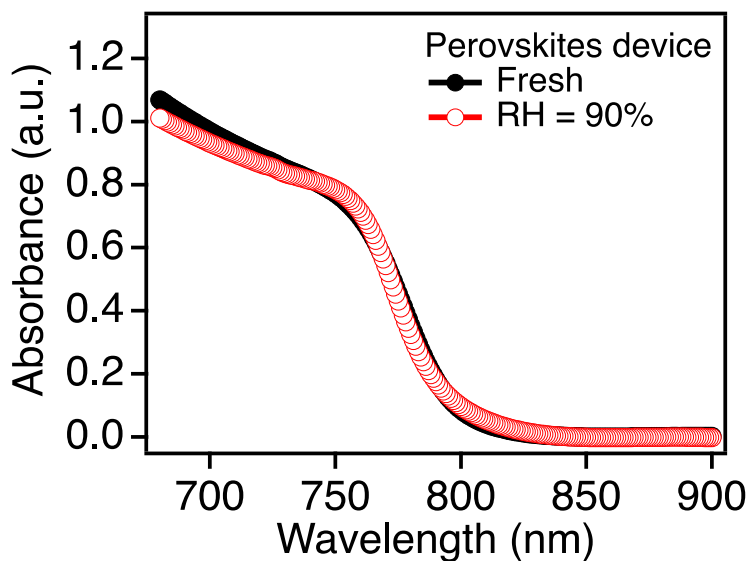

Figure S10. UV-Vis absorption spectra for the perovskites device before and after testing under CO_2 with R.H. = 90 % environment.
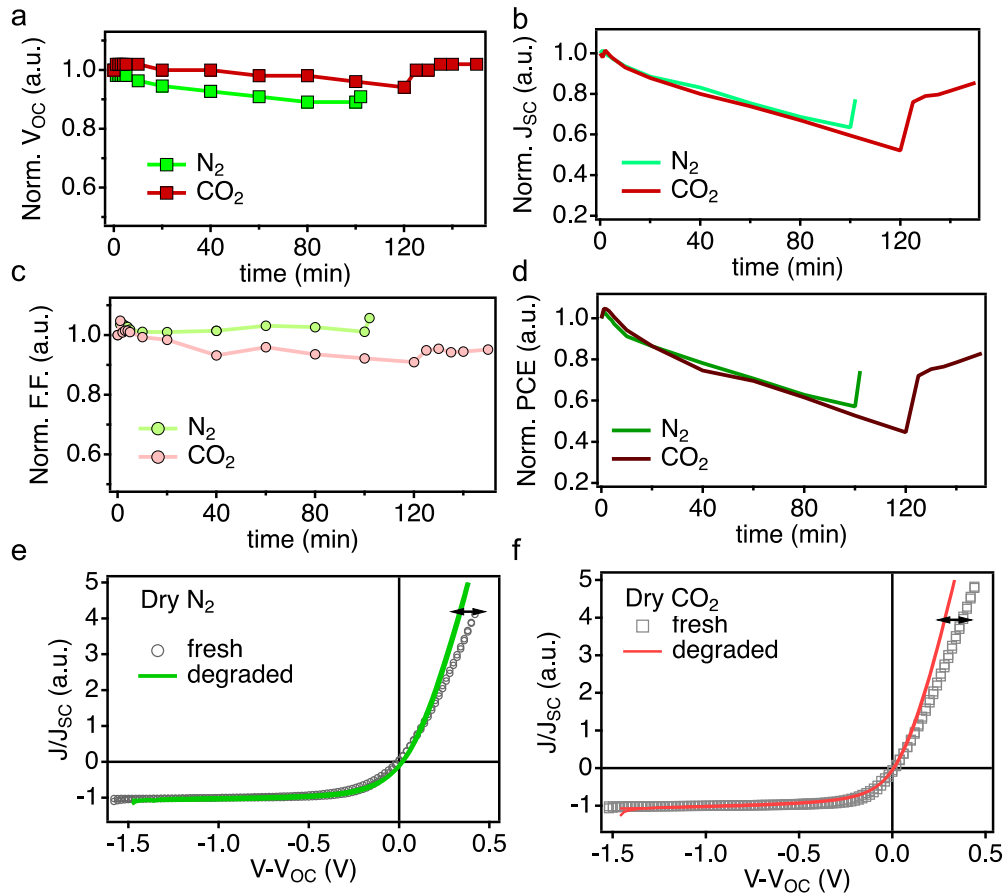
Figure S11 Detailed analysis for the device degradation behavior in dry N_2 versus dry CO_2
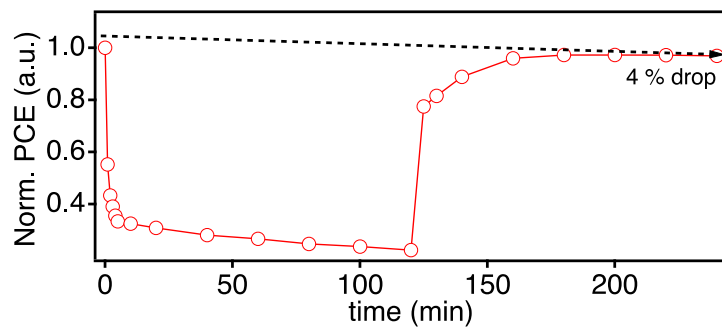

Fig. S12 Time evolution of the device's PCE for longer time (2-hr) of exposure to R.H. = 90 % in CO_2 gas.
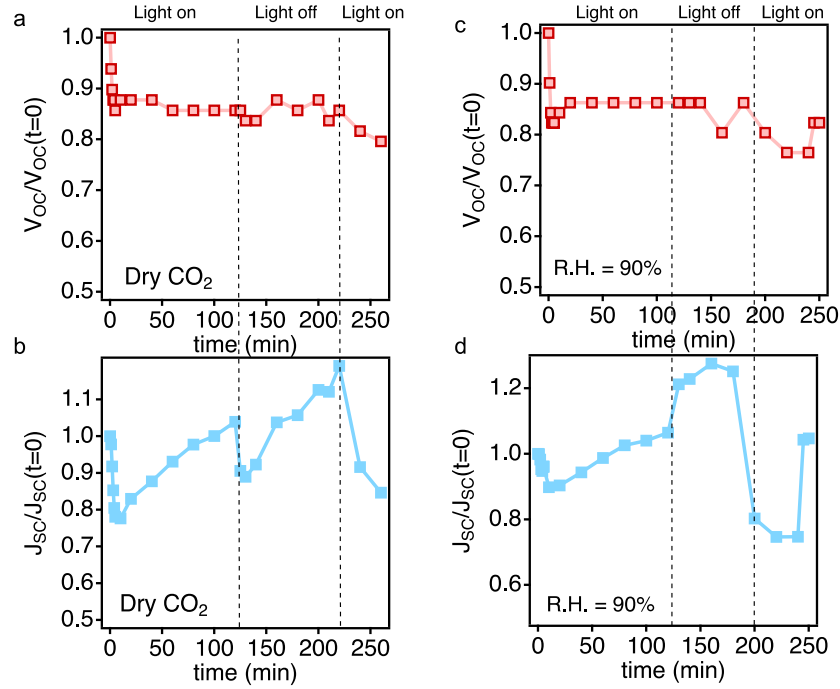
Fig. S12 device made with perovskite layer without ionic liquid additive. The degradation tests are performed under illumination and in dark for recovery observations. (a) &(b) are normalized V_{OC} and J_{SC} curves in dry CO_2, (c) &(d) are the same figure of merits in humid CO_2.
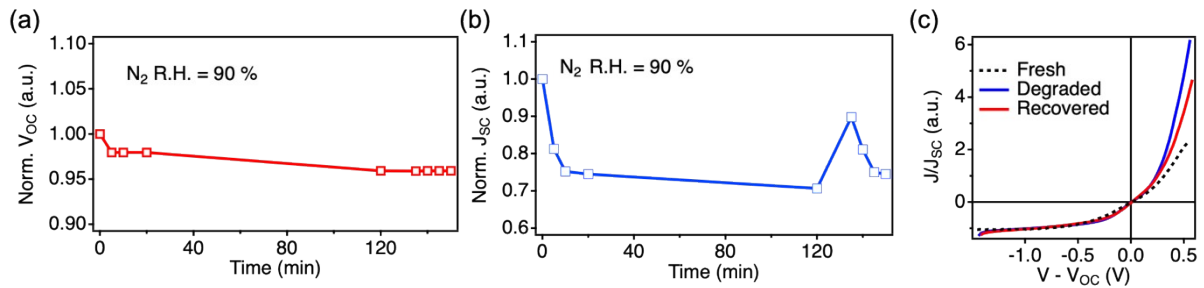

Fig. S13 The device's degradation behavior under N_2 with R.H. = 90 % The time evolution of (a) normalized V_{OC} and (b) normalized J_{SC} when exposed under constant illumination. (c) normalized JV curves to compare the JV behavior before and after degradation.