Temperature-dependence studies of Organolead Halide Perovskite-Based Metal/Semiconductor/Metal Photodetectors

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Supplementary material:

Space charge limited conduction (SCLC): the internal field is dominated by free or trapped carriers. Poole Frankel conduction (P-F): the current can arise due to release of carriers from traps under electric field. Fowler Nordheim tunneling (F-N): charge carriers tunnel from the electrode fermi level into the conduction band of the perovskite. The equations for these mechanisms are shown in Eq. S1-3.

$$\text{SCLC: } J = \frac{9}{8}\theta_f \varepsilon \mu V^n \qquad \text{Eq. S1}$$

$$\text{P-F: } J = \sigma_0 E \exp\left(\frac{-E_t}{k_B T}\right) \exp\left(\beta_{PF}\sqrt{E}\right) \qquad \text{Eq. S2}$$

$$\text{F-N: } J = \frac{q^3 m}{8\pi h m^* \varphi_b} E^2 \exp\left(-\frac{8\pi\sqrt{2m^*}}{3qh}\frac{1}{E}\right) \qquad \text{Eq. S3}$$

Where d is the thickness of perovskite, μ is charge carrier mobility, ε is the permittivity of perovskite, θ is the ratio of free charge carrier concentration, E_t is the trap energy, k_B is Boltzmann constant, T is temperature, σ is zero field conductivity, E is electric field, q is carrier charge, m is free electron mass, m* is effective electron mass, h is Planck's constant, and φ_b is the barrier height.

F-N tunneling mechanism fitting curves at temperatures vary from 300K to 350K are illustrated in Fig. S1a and b. No negative slop exists for the whole fitting curves, showing that F-N tunneling mechanism does not work. P-F mechanism fitting curves at temperatures vary from 300K to 350K are given in Fig. S1c and d. No positive slop exists for the whole fitting curves, proving that P-F mechanism does not work.

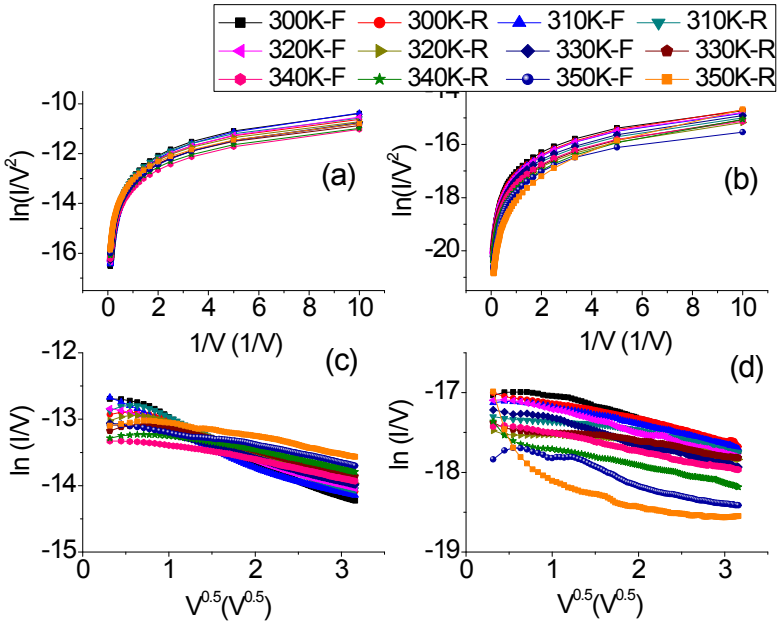


Figure S1. Mechanism fitting curves at temperatures vary from 300 to 350k (a) F-N tunneling, under light: 10 mW/cm^2 (b) F-N tunneling, under dark (c) P-F mechanism, under light: 10 mW/cm^2 (d) P-F mechanism, under dark

Fig. S2 illustrates the current at different upper limit voltage (5-70V) under illumination at room temperature. The value of current will reach 15 μA as the product of electrical field and the mobility will gradually approach to the limit.

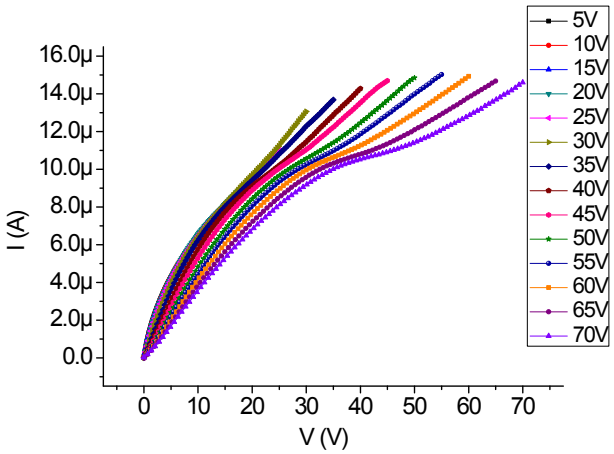
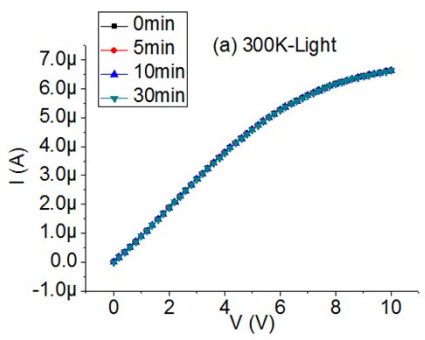
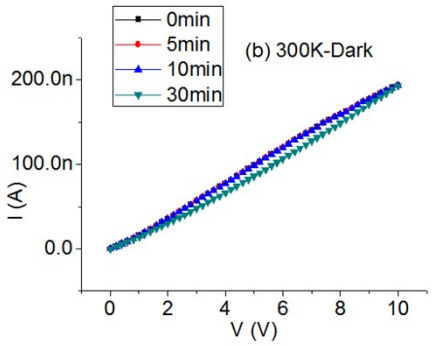
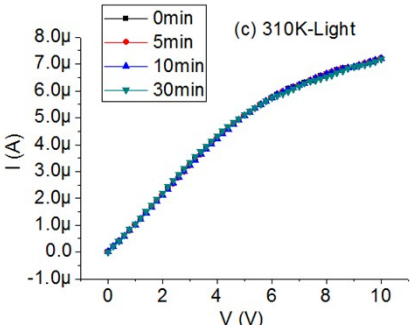


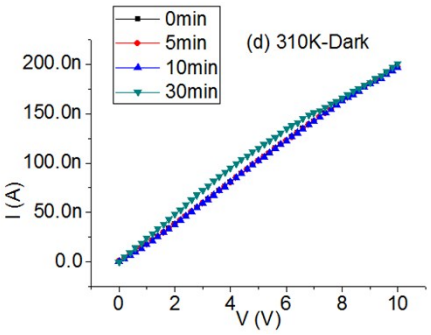
Figure S2. Current at different upper limit voltage (5-70V) under illumination at room temperature.

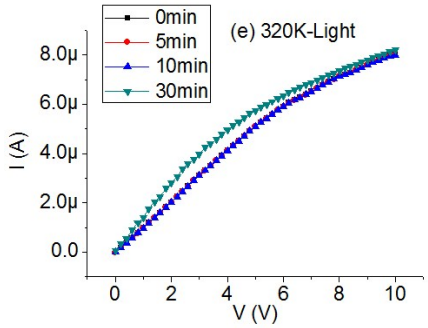
The effect of temperature on the stability and performance of perovskite-based photodetector as a function of operation time (0, 5, 10, and 30 min) is given in Fig. S3(a-l), and the XRD spectra and UV-Vis spectra of perovskite layer at different temperatures are provided in Fig. S4a-b. The photodetector under illumination shows stable properties even after 350K heat treatment of 30 min. However, the stability in the dark gradually becomes week as the temperature increases.

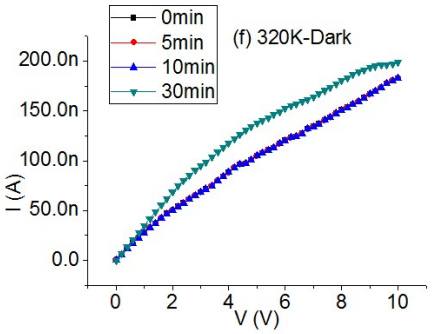

0min
5min
10min
30min
(a) 300K-Light
I (A)
V (V)

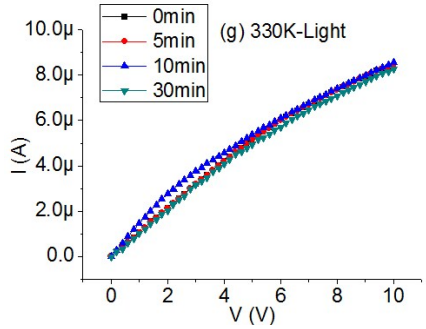

0min
5min
10min
30min
(b) 300K-Dark
I (A)
V (V)

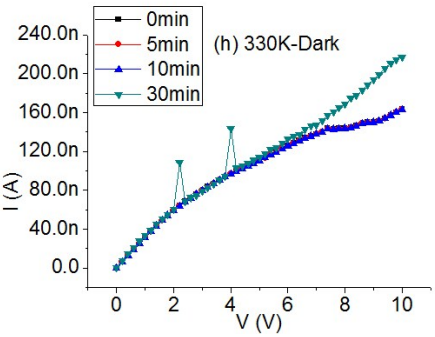

0min
5min
10min
30min
(c) 310K-Light
I (A)
V (V)


0min
5min
10min
30min
(d) 310K-Dark
I (A)
V (V)


0min
5min
10min
30min
(e) 320K-Light
I (A)
V (V)


0min
5min
10min
30min
(f) 320K-Dark
I (A)
V (V)


0min
5min
10min
30min
(g) 330K-Light
I (A)
V (V)


0min
5min
10min
30min
(h) 330K-Dark
I (A)
V (V)

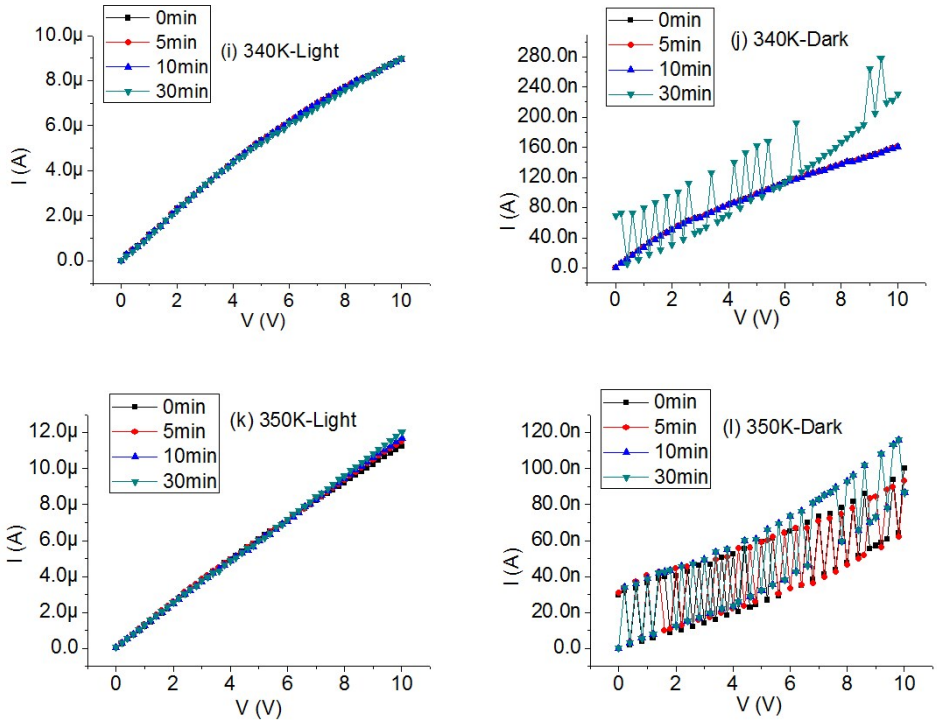


Figure S3. Effect of temperature on the stability and performance of perovskite-based photodetector as a function of operation time (0, 5, 10, and 30 min) (a), (c), (e), (g), (i), (k) 300K-350K under 10 mw/cm^2 light intensity. (b), (d), (f), (h), (j), (l) 300K-350K in the dark.

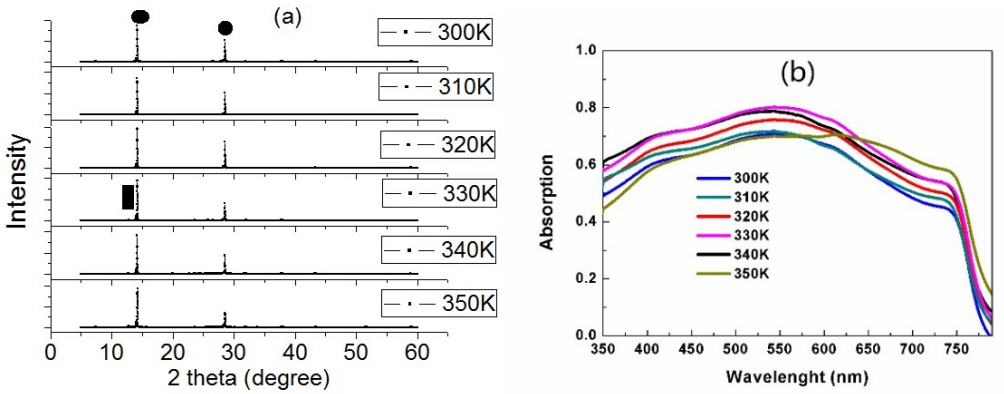


Figure S4. (a) XRD spectra and (b) UV-Vis spectra of perovskite layer at different temperatures. The peaks assigned to the perovskite (●), and lead iodide (▉) are labeled.