Elucidating the Fullerene Passivation Effect in $CH_3NH_3PbI_3$ Planar Heterojunction Perovskite Solar Cells

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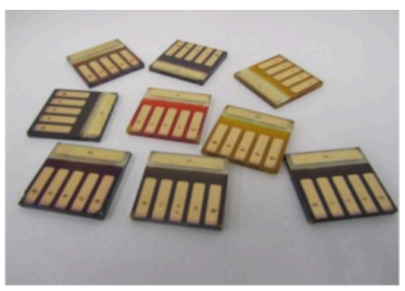
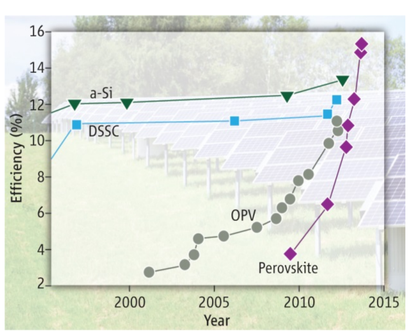
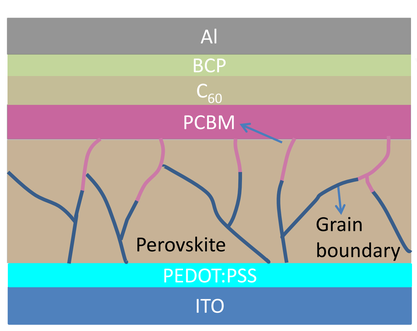
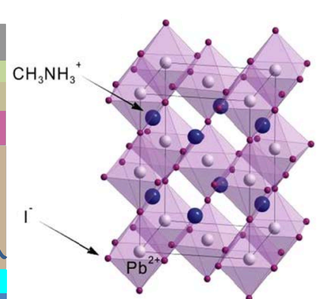
Introduction



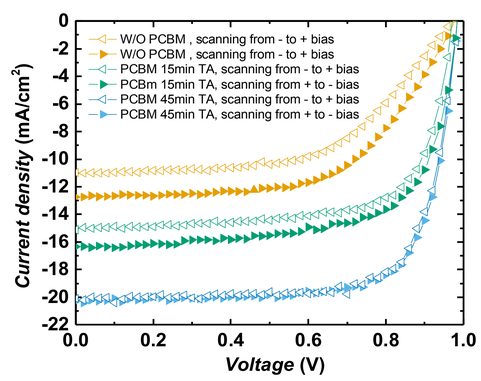
- Perovskites trigger the development of new device architectures in energy conversion.
- Efficiency has been doubled in less than a year and over 15% now
- Unique fabrication methods including interdiffusion and double fullerene layer developed by our group pave the way for further trap density study.

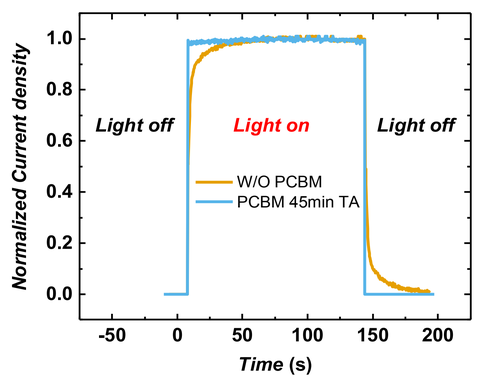






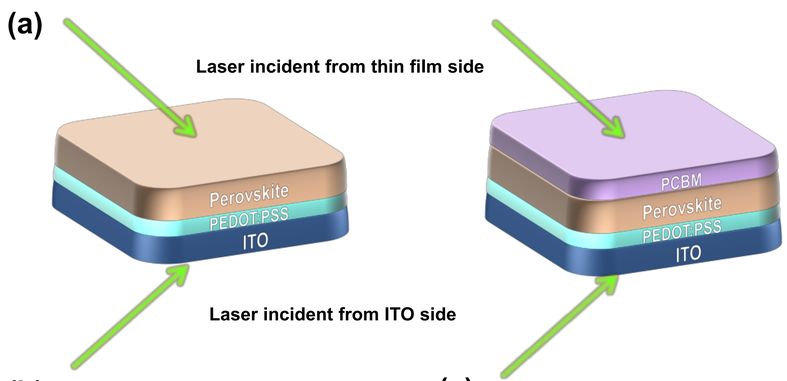
Research Motivation





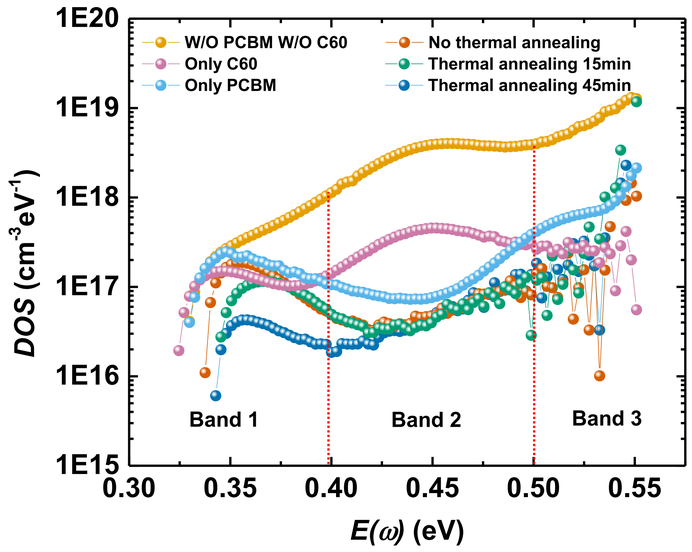
- A large hysteresis of photocurrents is wildly observed in perovskite solar cells and other defect-rich electonic devices.
- Trap density of state (tDOS) has significant effect on the hysteresis of photocurrent and efficiency of the devices
- A slow rising of photocurrent to maximum value in a long duration of 75 s upon turning on the illumination, corresponding to the trap filling process, indicating large tDOS

Photoluminescence (PL) measurements



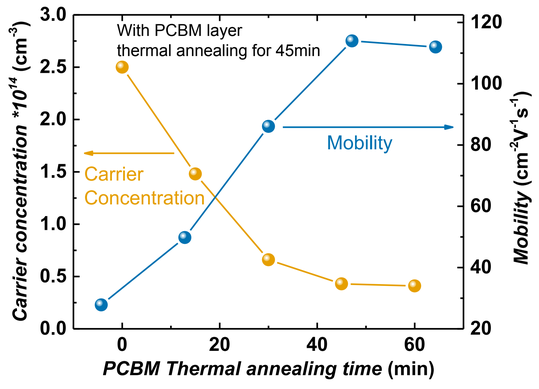
- PCBM effectively passivate the trap states on the top surface and at grain boundaries of perovskite thin films.
- It can also be inferred that the unpassivated charge traps close to the ITO side have negligible impair to the hole collection, and the traps are most likely ***electron traps***.
- It also points out ***the new direction to further increase the efficiency of the perovskite*** solar cells using new strategies to passivate traps in perovskite films closer to bottom surface.

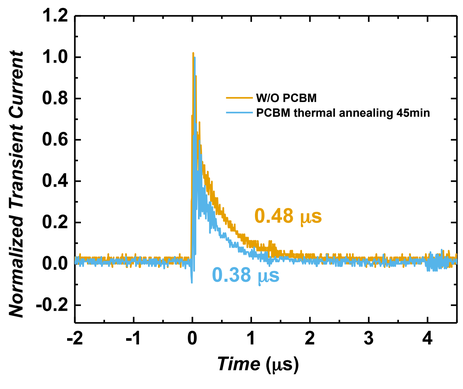
Thermal Admittance Spectroscopy (TAS) for tDOS

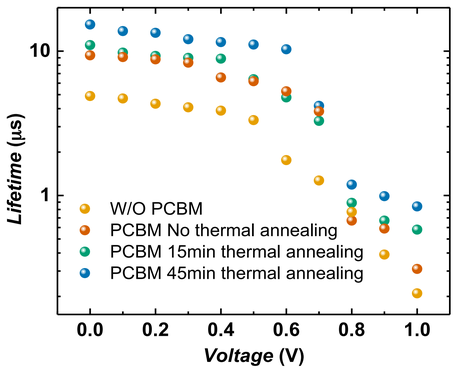


- Thermal admittance spectroscopy (TAS) analysis was used to further quantize the reduction of trap states in perovskite films by the passivation of PCBM.
- The deep traps locate at the surface of the perovskite film which can be passivated without thermal annealing, while the shallow trap states stay deeper in the perovskite films, such as grain boundaries inside the perovskite layer, which can only be passivated by the diffusion of PCBM into the perovskite layers

Mobility







- The passivation yielded a threefold increase of Hall mobility and a fourfold increase of charge carrier lifetime, and blue-shifted photoluminescence, and reduced trap density by two orders of magnitude
- These improved properties contribute to the enhancing efficiency from ***7.3%*** to ***14.9%***

Conclusions

- PCBM, which was originally designed as electron acceptor and electron transport material in the planar heterojunction perovskite solar cells, can effectively passivate these trap states.
- The mitigation of defect states is effective which can be deduced from the significant increasing of photocurrent response speed and decreasing of the tDOS.
- The improving properties of devices with optimum PCBM thermal annealing time, including longer charger carrier lifetime and larger mobility, contribute to the very good device performance

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