High Gain and Low-Driving-Voltage Photodetectors Based on Organolead Triiodide Perovskites

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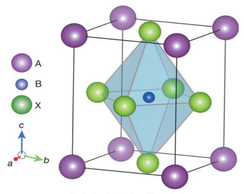
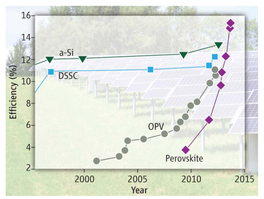
Research Motivation



$CH_3NH_3PbX_3$

A is methylammonium, B is Pb, and X is I, Br, or Cl.



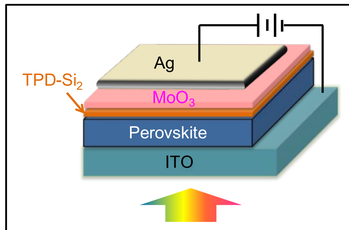
The rapid increase in perovskite solar cell efficiency

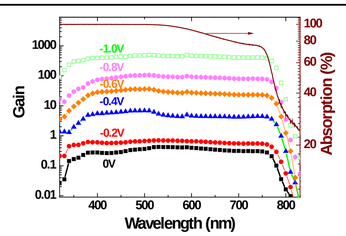
Very promising as photodetector materials

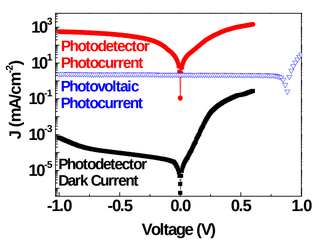
Merits of perovskite material:

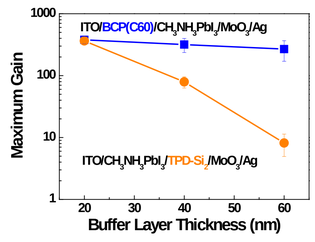
- High carrier mobility (larger than 100 cm^2/Vs)
- Low temperature fabrication (around 100 °C) and solution-processable
- Tunable bandgap (from UV to near-IR)

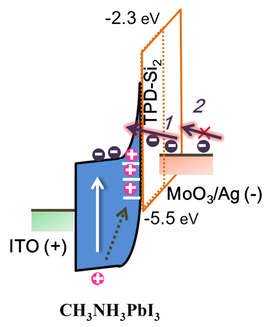
Device Structure and Working Mechanism





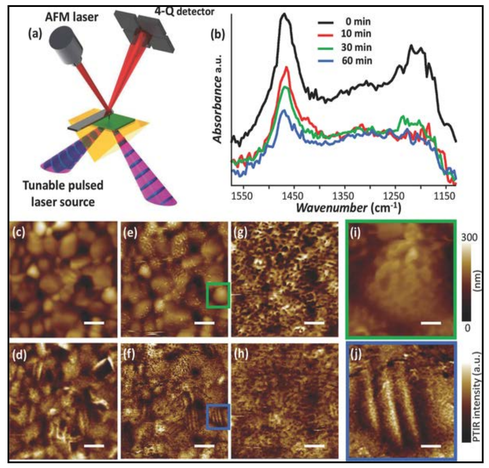




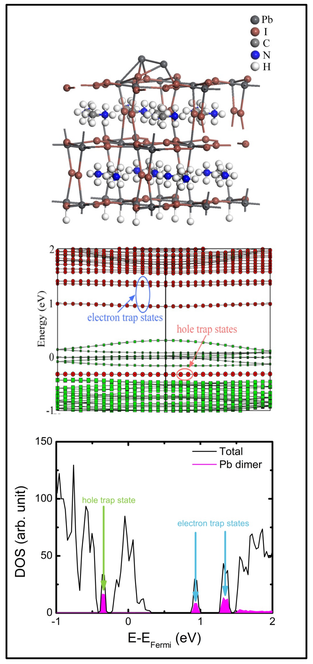


- The device shows high photoconductivity gain of >400 at a very low bias of -1 V
- The photocurrent of the photodetector is several hundred times higher than that of the photovoltaic device under 0.1 sun illumination
- The charge injection side is determined to be from the anode
- The surface hole trap induced electron injection is responsible for the high gain of the device

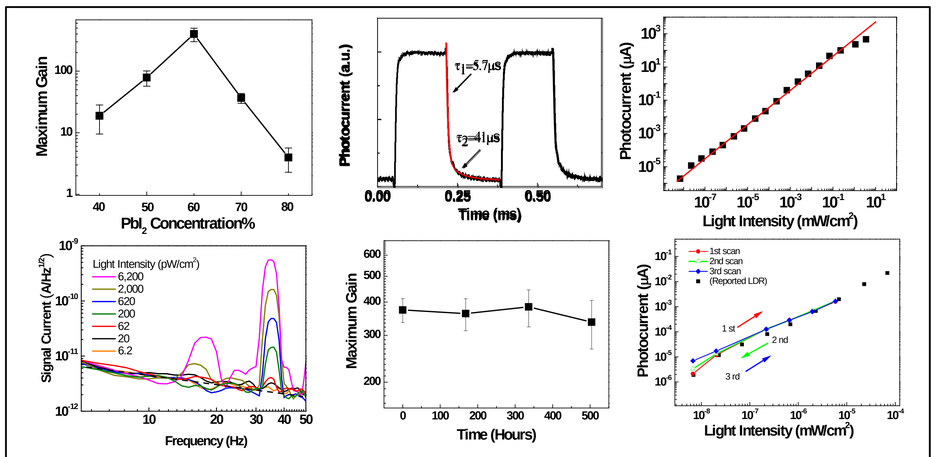
Origin of the Surface Charge Traps



- The decomposition of perovskite film under thermal annealing leads to the formation of methylammonium-deficient top surface as identified by photothermal induced resonance (PTIR)
- Density functional theory (DFT) calculation confirms that the Pb^{2+} clusters on the surface tend to form trap states



Photodetector Performance Characterization



- The device shows a high gain of >400, short response time of 5.7 μs, large linear dynamic range of 85 dB, and high sensitivity with lowest detectable light intensity down to 6.2 pW/cm^2
- The device can be stable in air for more than 600 h without encapsulation, and can produce stable photocurrent output under repeated operation

Conclusions

1. A highly sensitive organolead triiodide perovskite based photodetector was demonstrated with a broadband response ranging from the UV to the NIR
2. The photodetectors showed a very high gain >400 at very low bias of -1 V
3. The hole traps caused by large concentration of Pb^{2+} cations on the perovskite film top surface is critical for achieving high gain in these devices
4. The device performance is comparable or better than that of the commercial Si photodetector
5. The extremely low bias needed for these photodetectors enables powering them with miniature button batteries and/or compact integration with existing low voltage circuits

References

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Acknowledgements

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