

Perovski[rrrtt]te: A New Direction in Solar Technology



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Introduction

Fossil fuels are a limited resource that will not meet the demands of an exponentially growing human population. The obvious unlimited power source is our sun that will continue to burn for 5 billion more years. Harvesting solar energy is a challenge that has been in the works for many decades, and scientists have been balancing cost, performance and stability. With a market value of over \$1 trillion world wide¹⁵, the renewable energy industry could be revolutionized by the recent discovery of high performance, low-cost perovskite solar cells.

Type of cell	Record efficiency (%)	Module cost (\$/W)	Advantages	Disadvantages
Silicon (single crystal)	25.6	1.77-3.09	Stable	Requires direct sunlight, rigid
Perovskite	22.1	0.21-0.28	High efficiency, low cost, flexibility	Pb dependent, scaling & stability issues
Dye-sensitized	11.9	0.75-3.22		Stability issues, low efficiency
Organic	11.5	1.00-2.83		Stability issues, low efficiency

Table 1: Comparing select record solar cell efficiencies, module costs for industrially reasonable efficiency solar cells. Silicon is the most established type of commercial solar cell.¹⁻⁴

Perovskite Crystal Structure

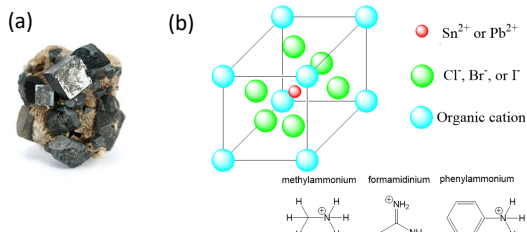


Fig. 1: (a) A Perovskite crystal.⁵ (b) Crystal structure of MAPbX₃ perovskites.⁶

References

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Mechanism

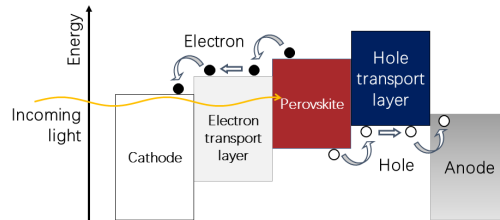


Fig. 2: (a) Schematic for design of a heterojunction perovskite solar cell. (b) Band energies of the perovskite absorber layer and the electrodes.⁷

- Perovskite absorbs light and generates electron-hole pair
- Electrons and holes migrate to electrodes due to energy differences, creating a voltage across the cell

Device Processing

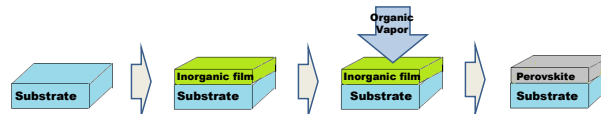
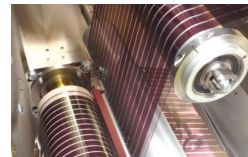


Fig. 3 : (Above) Sequential deposition of inorganic PbI₂ & organic MAI components by thermal evaporation.⁸ (Right) Roll-to-roll production of organic solar cells.¹⁴

- Roll-to-roll printing w/o vacuum in ambient conditions allows for cheap, quick production
- Thousands of cells can be printed on long, flexible sheets



Device Performance

- Different compositions lead to different performances & can combine for desirable photocurrent
- Perovskite can be tuned to absorb different wavelengths

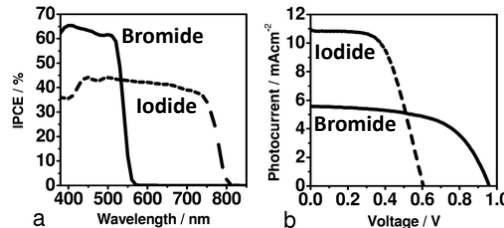


Fig. 4: Performance of the first perovskite cell ever constructed in 2009 by the Miyasaka lab. (a) light absorption at different wavelengths; (b) current-voltage scan. This cell has 3.8% efficiency.⁹

Societal Impact

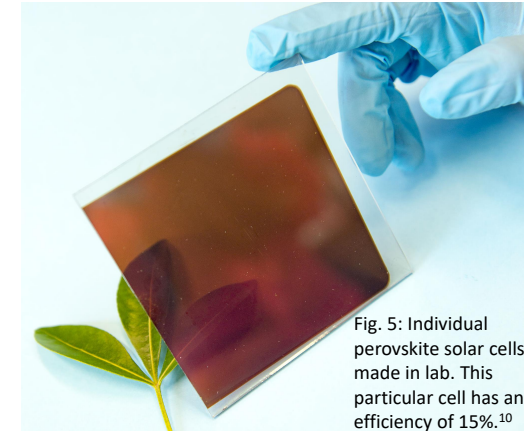


Fig. 5: Individual perovskite solar cells made in lab. This particular cell has an efficiency of 15%.¹⁰

- Potentially upends sustainable energy with unparalleled low cost & efficiency
 - Cheap, solution-based low-temp processing³
- Lower cost → widespread residential rooftop solar
 - Current Si initial investment restricts accessibility
 - Perovskite decreases cost upfront & time to savings
 - More rooftop solar = more pressure on companies to enact favorable consumer net-metering policies
- Applications in telecommunications, light emitting diodes, and solar-to-hydrogen fuel production¹¹⁻¹²

Future Work and Challenges

- Lead is toxic & crystals are water soluble¹³
- Perovskite solar cells have poor life times
 - Materials have intrinsic instability¹³
- Degradation results in poor device durability
 - Problems: air (oxidation), irradiation, water
 - Solutions: encapsulation, chemical stability
- Synthesize larger/better crystals
 - Manipulate spectrum absorption: tandem
 - Enhance charge transfer