Perovskite Technologies

Background

Organic-inorganic hybrid materials, particularly perovskites, represent a new class of materials that may combine desirable properties of both organic and inorganic materials in photovoltaic applications. Organic materials have low manufacturing costs while inorganic materials typically produce higher performing devices, but require expensive, complicated manufacturing. Perovskite hybrid materials have been proven to combine the high performance of inorganic materials with the flexibility of organic materials. However, the highest performing perovskite-based devices typically are fabricated using costly vacuum deposition techniques and high temperatures. Solution processing methods, along with improvements in performance, would allow the perovskite-based electronic devices to be competitive alternatives to traditional silicon and other inorganic technologies.

Lead halide perovskite solar cells offer excellent photovoltaic efficiencies (up to 15%), but both the perovskite material and the charge transport layers have poor stability, where the device degrades within days under normal conditions. Specifically, organic charge transport layers are important for energy level matching and charge transport, but their use is limited because they have poor device stability and are costly to fabricate. The use of inorganic materials to replace the organic transport layers offers a promising avenue to circumvent the disadvantages of these layers for solar cell applications.

Over the last decade, the certified power conversion efficiency (PCE) of perovskite solar cells has increased to 23.1%, establishing perovskites as viable alternatives to the widely used silicon solar cell. Further PCE improvement can be achieved by reducing the microscale heterogeneity of the films, but conventional techniques to improve crystal growth are time consuming. Therefore, novel scalable and efficient strategies that improve microscale properties will be important to further enhance the photovoltaic properties of perovskite solar cells. Another technique for PCE improvement is adopting a tandem architecture, which uses multi-junction solar cells to harness a broader range of the solar spectrum. While this design is typically implemented in III-V semiconductors to achieve ~30% efficiencies, their high fabrication costs hinder mass commercialization. Therefore, applying tandem architectures to solution-processed perovskite solar cells could provide a pathway for improved PCEs at commercially viable costs.

Low-Temperature Solution-Processed Perovskite Solar Cells with High Efficiency and Flexibility

Professor Yang and colleagues have developed a solar cell device based on perovskite materials that uses common, inexpensive polymer materials as the hole and electron transport layers with a demonstrated efficiency of 15%. Currently used TiO_2 requires high temperature processing to deposit high quality films. By using solution processable polymer materials, the manufacturing process can be simpler and cheaper, while allowing for the use of flexible plastic substrates. This technology removes a significant barrier to widespread use of perovskite-based electronics.

Reference: UCLA Case No. 2014-734

Amorphous Silicon and Polymer Hybrid Tandem Photovoltaic Cell

Researchers led by Professor Yang Yang have invented a novel hybrid tandem solar cell that combines amorphous Si with a conjugated polymer layer to achieve a tested efficiency of 10.5%, with potential efficiencies as high as ~13.5% after optimization. These materials are advantageous because they can be manufactured with inexpensive roll-to-roll techniques. The combination of organic and inorganic materials used in this technology makes for a low-cost, lightweight, and flexible solar cell.

Reference: UCLA Case No. 2015-152

Efficient and Stable Perovskite Solar Cells with All Solution Processed Metal Oxide Transporting Layers

Professor Yang Yang and his research team have developed a unique perovskite solar cell that uses metal oxide films for the charge transport layer. Metal oxides offer the advantage of higher carrier mobility and superior stability than typical organic materials and they can be processed easily *via* solution. This unique lead halide perovskite solar cell has achieved a ~16% efficiency and improved stability of 60 days under normal operating conditions.

Reference: UCLA Case No. 2015-556

Highly Efficient Perovskite/Cu(In,Ga)Se2 Tandem Solar Cell

Researchers led by Professor Yang Yang have developed Perovskite/Cu(In, Ga)Se2 (PVSK/CIGS) tandem photovoltaic devices with ~22% efficiency. These PVSK/CIGS tandem solar cells have double the efficiency as similar structures. The solar cells do not need high vacuum facilities for processing, which could reduce the fabrication costs. Moreover, only a commercialized CIGS rear cell is needed to achieve high efficiencies versus Silicon/PVSK tandem solar cells which require a high-quality Silicon rear cell. Additionally, because this is a thin film solar cell, flexible tandem solar cells could be fabricated by this method.

Reference: UCLA Case No. 2018-019

A Bi-Functional Lewis Base Additive for Microscopic Homogeneity in Perovskite Solar Cells

Researchers led by Professor Yang Yang have developed a novel strategy to decrease heterogeneity in perovskite thin films by adding novel Lewis bases. The additives have been shown to improve microscale properties by enhancing crystallinity and decreasing grain boundaries and related defects. The bases can be easily added to the solution before further processing and do not need to be removed after crystal growth. Perovskite devices using this method demonstrated a 10% increase in power conversion efficiency (PCE) and the best performing device achieved a PCE of 18.6%.

Reference: UCLA Case No. 2018-020

2D perovskite stabilized phase-pure formamidinium perovskite solar cells and light emitting diodes

Professor Yang Yang and his research team have developed a highly efficient and stable lead halide perovskite solar cell based on a mixture of formamidinium perovskites and 2D perovskites. These phase-pure $FAPbI_3$ films demonstrate improved crystallinity and an order of magnitude enhanced photoluminescence lifetime. Moreover, the 2D perovskites protect the $FAPbI_3$ from moisture, resulting in significantly enhanced moisture stability. Devices reached a power conversion efficiency (PCE) of 21.06% and the device retains 98% of initial PCE for 1392 h (58 days) storage under ambient condition.

Reference: UCLA Case No. 2018-745

Potential Applications

- Grid solar cells
- Portable solar cells
- LEDs
- Field-effect transistors
- Wearable electronics

Advantages

- High performance electronic devices, including solar cells with up to ~20% efficiency
- Solution processable – low-cost and versatile manufacturing
- Uses inexpensive, well-studied materials for many layers
- May use a variety of substrates, including flexible plastics
- Enhanced and controlled reconstruction between organic and inorganic components during film formation leading to superior device performance
- Continuous, compact, large grain size, full surface coverage of PVSK thin films
- Technique applicable to a range of substrates and devices including flexible films, multi-junction solar cells, LEDs, sensors and superconductors

Development-to-Date

Prototype perovskite-based solar cell devices have been fabricated with efficiencies up to ~20%.

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