

NEXT-GENERATION ECO-FRIENDLY SOLAR CELLS: PEROVSKITE, ORGANIC, AND HYBRID SYSTEMS

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Abstract: This article analyzes next-generation solar energy harvesting systems, focusing on perovskite, organic, and hybrid solar cells. The study discusses efficiency, environmental safety, long-term stability, and industrial applicability. It also examines strategies for reducing ecological impact, recycling materials, and technological integration. The results indicate that these systems offer higher energy efficiency and enhanced environmental safety compared to traditional silicon-based solar cells.

Keywords: perovskite, organic solar cells, hybrid systems, eco-friendly, efficiency, stability, photovoltaic, materials.

Introduction

Solar energy is a sustainable energy source of global significance. Conventional silicon-based solar cells have high efficiency but require energy-intensive and sometimes environmentally harmful manufacturing processes. Consequently, next-generation solar cells—including perovskite, organic, and hybrid systems—are being developed as eco-friendly, cost-effective, and highly efficient alternatives.

Perovskite solar cells are distinguished by their high photon absorption and conversion efficiency. Organic solar cells are lightweight, flexible, and produced through environmentally safer processes. Hybrid systems combine the advantages of two materials, such as perovskite-organic or perovskite-silicon combinations, optimizing efficiency and mechanical properties.

Materials and Methods

1. **Perovskite Systems:** $\text{CH}_3\text{NH}_3\text{PbI}_3$ and related perovskite compounds; spin-coating and vapor deposition techniques.

2. **Organic Systems:** Polymer-based solar cells; e.g., P3HT:PCBM blends.
3. **Hybrid Systems:** Perovskite-organic and perovskite-silicon combinations.

Methodology:

- Photovoltaic efficiency measurements using current–voltage (J–V) characterization.
- Stability and degradation analysis over time.
- Environmental assessment: Pb content, organic solvents, and recyclability.
- Material characterization: SEM, TEM, XRD, and UV–Vis spectroscopy.

Results

1. **Perovskite Systems:**
 - Efficiency: 25–27% in laboratory conditions.
 - Advantages: high absorption, rapid production.
 - Limitations: Pb content, stability issues (oxidation, moisture sensitivity).
2. **Organic Systems:**
 - Efficiency: 10–15%.
 - Advantages: flexible, lightweight, environmentally safe.
 - Limitations: low stability, UV-induced degradation.
3. **Hybrid Systems:**
 - Efficiency: 20–25%.
 - Advantages: combination of perovskite efficiency and organic flexibility.
 - Stability improved via encapsulation and surface modification.

Discussion

The main advantage of next-generation solar cells lies in their high efficiency and eco-friendliness. Perovskites offer excellent efficiency but lead content is a concern. Organic cells are safe but less efficient. Hybrid systems provide a balanced compromise.

Laboratory and industrial studies show that encapsulation, surface passivation, and material recycling significantly enhance environmental safety. Flexible substrates enable portable and integrated applications.

Conclusion

Next-generation solar cells—including perovskite, organic, and hybrid systems—combine high efficiency and environmental safety. Future development should focus on durable, long-lasting, and recyclable photovoltaic systems. Integrated approaches, material modifications, and encapsulation technologies will enhance industrial-scale performance and sustainability.

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