

India and the Future of High-Efficiency Solar Cells: Why It Should Not Miss the Bus

The article discusses the advancements in **high-efficiency solar cells**, particularly those based on **perovskite technology**, and highlights India's position in this evolving field. It provides an overview of the **scientific developments, global leadership in solar technology, and India's potential to catch up in the race for efficient solar energy production**. Below is an elaborate breakdown of the article's key points, facts, and figures.

1. The Breakthrough Discovery of Perovskite Solar Cells

Tsutomu Miyasaka's Game-Changing Research (2009)

- Japanese professor **Tsutomu Miyasaka** discovered the potential of **perovskites** for solar cells while researching **dye-sensitized solar cells** in 2009.
 - Perovskites are a **unique class of materials named after the Russian scientist** who first discovered them. They stand out due to their **distinctive crystal structure** and their ability to absorb light efficiently.
 - Initially, perovskite-based solar cells had an **efficiency of only 3.8%**, but researchers knew this could be improved.
 - The discovery triggered an international race to **stabilize perovskites** and integrate them into solar energy technology.
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2. Perovskite Tandem Cells: The Future of Solar Energy

What Makes Perovskite Tandem Cells Special?

- Today, **perovskite tandem solar cells** (which combine perovskite layers with conventional silicon cells) are showing great promise in **enhancing solar energy conversion efficiency**.
- The efficiency of conventional solar cells has plateaued at around **23-24%** with the latest **TopCON (Tunnel Oxide Passivated Contact) technology**.
- **Perovskite tandem cells** can surpass **30% efficiency**, which is a significant jump in the field.

How Perovskites Improve Efficiency?

- Perovskite absorbs **high-energy blue light**, while silicon absorbs **low-energy red light**, enabling **better overall utilization of the solar spectrum**.
 - This layered approach leads to **super-high efficiency** and lower solar energy costs.
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3. China's Leadership in Perovskite Solar Technology

China is **leading the global race** in perovskite-based solar technology:

- In **June 2024**, Chinese solar giant **LONGi** achieved a record **34.6% efficiency** in its silicon-perovskite solar cells. The **theoretical maximum efficiency** of such cells is **43%**.

- **Microquanta**, another Chinese firm, announced in **December 2024** that it had shipped **50 MW of silicon-perovskite tandem modules** with **25.4% efficiency** to a customer.
 - However, **efficiency slightly decreases** when individual solar cells are assembled into full-scale modules.
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4. India's Position in High-Efficiency Solar Cells

India, which **missed the earlier opportunity to dominate solar cell manufacturing**, is **not too far behind in perovskite technology**.

Notable Research and Innovations in India

1. IIT Bombay

- Prof. **Dinesh Kabra** developed a **perovskite tandem cell** with **29.8% efficiency**.
- The government granted **\$10 million** to his startup **ART-PV India** to build a **pilot plant for perovskite tandem cells**.
- **First Solar** and **Waaree** have agreed to support ART-PV in **cash and kind** in return for **preferential licensing** of the technology.

2. IIT Roorkee

- Scientists developed a **solution-based fabrication approach** to create **semi-transparent perovskite solar cells**.
- Their method involves coating **crystalline silicon** with **PEDOT:PSS** and overlaying it with a **thin perovskite film**.
- These cells are **cost-effective** and have been tested with **glass-over-glass encapsulation** for over **two years of stability**.
- A startup **Perovskite Innovation** (formed by IIT Roorkee researchers) won the **Indian Oil Corporation Challenge grant** for further development.

Industry Players' Interest in Perovskite Technology

- **First Solar** (global leader in thin-film solar modules) is **keen on perovskite technology** due to its similarity with their existing **coating-based technology**.
 - **Avaada Energy** (building a **3-GW wafer, cell, and module plant**) stated that their facility would be **capable of incorporating perovskite technologies**.
 - **Tata Power Solar and Vikram Solar** have not commented on their perovskite initiatives yet.
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5. The Path Ahead: India's Golden Opportunity

Why India Must Act Now

- India **missed the manufacturing opportunity** during the initial solar cell and module boom.
- Perovskite tandem technology provides a **new window of opportunity** to catch up and compete with China.

- With the **right funding, research backing, and industry adoption**, India could become a leader in high-efficiency solar technology.

Expected Timeline

- Within the next 5 years**, silicon-perovskite tandem cells are expected to become **commonplace** in the solar energy market.
 - Their **impact on solar energy costs** will be **significant**, making solar power **cheaper and more efficient**.
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Conclusion: A Pivotal Moment for India in Solar Energy

- Perovskite tandem cells represent the next big leap in solar energy efficiency**, with efficiencies exceeding **30%**.
 - While China is currently leading, **India has the opportunity to establish itself as a serious competitor** through **academic research, industrial partnerships, and government support**.
 - Strategic investment in perovskite technology** could allow India to avoid **repeating its past mistake** of missing the solar manufacturing revolution.
 - If successful, this technology will **drastically lower solar energy costs** and **enhance India's renewable energy capabilities, boosting both energy security and economic growth**.
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This moment is **critical for India**—it must **act swiftly** to ensure it does not **miss the bus again** in the next big revolution of solar technology.