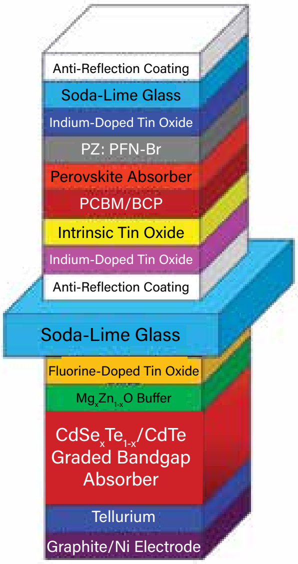
CdTe-Perovskite Tandem Photovoltaics Achieve Record Efficiency

Achieving energy sustainability necessitates efficient, cost-effective renewable energy solutions such as photovoltaics, which convert solar energy to electricity. A growing share of commercial solar cells are made with polycrystalline cadmium telluride (CdTe) thin-film technology. CdTe solar cells of at least 1 cm^2 have demonstrated up to 21.1% conversion efficiency; however, improving their efficiency further has been difficult.

In photovoltaic devices, the junctions and their bandgaps determine the range of light wavelengths that can be absorbed and converted into electricity. Single-junction cells absorb a specific range of wavelengths limited by their single bandgap, while tandem cells utilize multiple bandgaps to absorb a broader spectrum of light more efficiently. While research to improve single-junction solar cell efficiency is ongoing, another approach is to use tandem solar cells.



▲ Researchers at Colorado State Univ. in collaboration with Indian Institute of Technology Bombay demonstrated 24.2% efficiency for a four-terminal two-junction CdTe-perovskite tandem solar cell. Perovskite and $CdSe_xTe_{1-x}$/CdTe layers absorb the light to generate electrical charge while other layers facilitate extraction of electricity and the glass substrate provides structural resilience.

Combining CdTe and metal-halide perovskites is especially promising for achieving high conversion efficiency at lower costs. CdTe is known for its near-optimal bandgap, high absorption coefficient, and low-cost manufacturing compared to silicon photovoltaic technology. Perovskites offer excellent light absorption, low-temperature thin-film fabrication, high power conversion efficiency, and flexibility of bandgap tuning, which is essential for tandem cell integration. Despite tandem solar cells being an established concept, limited research has explored CdTe.

Researchers at Colorado State Univ. (CSU), funded partly by the U.S. National Science Foundation (NSF), and the Indian Institute of Technology Bombay (IITB) have demonstrated a four-terminal (4-T) CdTe-perovskite tandem solar cell with an unprecedented power conversion efficiency of 24.2%. Previously, two-terminal (2-T) CdTe-perovskite tandem cells had demonstrated less than 10% efficiency.

Previous efforts on 2-T tandems faced optimization and reliability challenges. Using a 4-T instead of a 2-T device configuration avoids the need to match currents through each absorber layer and reduces fabrication complexities.

In this pioneering work by the CSU-IITB team, 18.3% efficient near-infrared-transparent perovskite solar cells were stacked on 19.56% efficient CdTe cells to form a 4-T tandem structure. Refractive optical losses between the tandem cells were largely mitigated using an index-matching liquid to achieve a tandem efficiency of 24.2%, demonstrating the potential of CdTe-perovskite tandem cells for commercial production.

The demonstrated efficiency of the 4-T CdTe-perovskite tandem cells provides an alternative to silicon-based perovskite tandem cells and opens new avenues for more affordable and efficient solar energy solutions. Future improvements will include fabricating films on both sides of the glass substrate, eliminating the need for the liquid, and simplifying the manufacturing process. A joint invention disclosure with CSU and IITB is in progress, with companies having expressed interest in its commercialization.

This work builds on earlier collaborations between CSU and Univ. of Texas at Austin (UTA) researchers with the Center for a Solar Powered Future (SPF2050), an NSF Industry-University Cooperative Research Center, which in 2019 demonstrated the potential of combining wide bandgap perovskite materials with CdTe in a tandem architecture. This foundational research highlights the crucial role of academic collaboration in advancing tandem solar cell technology.

"The demonstration of a successful CdTe-perovskite tandem photovoltaic device is an exceptional example of the potential outcomes that can be achieved from cooperative research centers such as SPF2050. The synergistic research being pursued by CSU along with UTA and IITB is poised to have a strong impact on future academic as well as commercial developments long-term for all forms of perovskite-based research," says Ray Lewandowski, co-chair of the Industrial Advisory Board for SPF2050. CEP

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