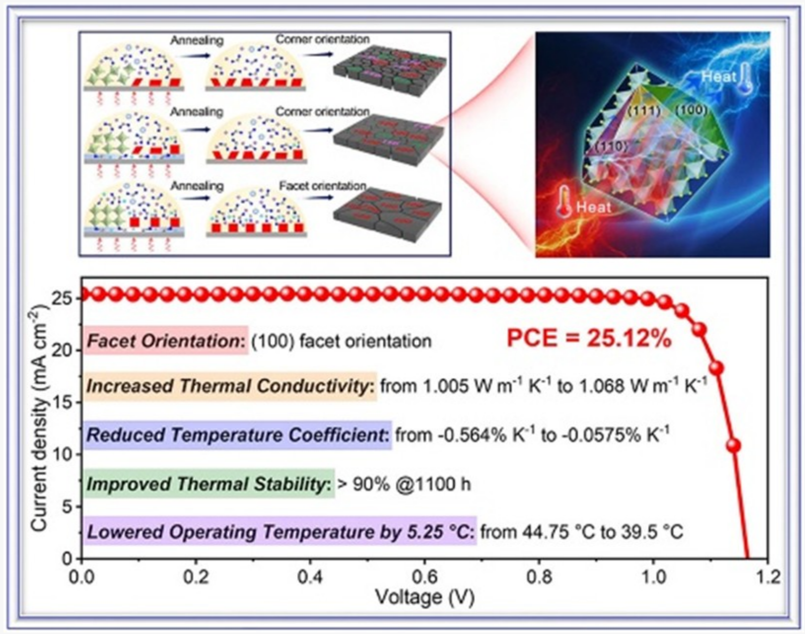
# Facet-oriented perovskite films deliver temperature-resilient solar power

GA, UNITED STATES, October 21, 2025 /EINPresswire.com/ -- Perovskite solar cells (PSCs) are widely recognized for their outstanding power conversion efficiency, but their vulnerability to heat undermines long-term stability and practical use. This study introduces a crystal facet engineering strategy to enhance thermal conductivity and reduce performance loss under elevated temperatures. By orienting the perovskite film toward the (100) facet, the researchers improved heat transfer, lowered operating temperature, and achieved stable power output even during prolonged illumination. The resulting inverted solar cells reached 25.12% efficiency while maintaining over 90% of initial performance after extended aging. These findings highlight thermal management through facet orientation as a powerful route to reliable, high-efficiency solar energy technologies.




Facet-Engineered Perovskite Films Enable Self-Cooling Solar Cells. Schematic and performance data highlight how (100) facet orientation enhances heat dissipation in perovskite solar cells. By increasing thermal conductivity, lowering operational temperatu

Over the last decade, perovskite solar cells (PSCs) have achieved record efficiencies rivaling or surpassing conventional silicon devices. Yet despite this rapid progress, a major obstacle remains: stability under real-world operating conditions. Continuous exposure to sunlight causes heat accumulation, triggering ion migration, lattice distortion, and irreversible degradation. Conventional approaches such as defect passivation and encapsulation improve durability but do not fully address the intrinsic problem of heat generation within the perovskite layer. Effective thermal management—ensuring rapid heat dissipation—has become a crucial step toward making PSCs commercially viable. Due to these challenges, deeper research on crystal facet engineering for temperature-resilient PSCs is required.

A research team from Shandong University of Science and Technology, Yunnan Normal University, and collaborating institutions has reported a novel facet-orientation strategy for PSCs in eScience (published online May, 2025). By introducing methylamine chloride to control crystallization, they achieved perovskite films dominated by the (100) crystal facet, which enhances thermal conductivity and reduces heat accumulation. The resulting inverted solar cells reached 25.12% efficiency and displayed remarkable operational stability, offering a pathway toward scalable, temperature-insensitive solar technology.

The study combined theoretical modeling and experimental fabrication to investigate the role of crystal orientation in thermal transfer within Cs0.03FA0.97PbI3 perovskite films. Density functional theory calculations showed that the (100) facet possesses superior heat transport properties compared to the (110) and (111) facets. Guided by this insight, the researchers incorporated methylamine chloride during film preparation to favor (100) facet growth. Measurements confirmed that thermal conductivity increased from 1.005 to 1.068 W m$^{-1}$ K$^{-1}$, lowering the device's equilibrium temperature by 5.25 °C. Performance testing demonstrated that the (100)-oriented devices not only reached a certified efficiency of 25.12% but also showed minimal efficiency drop with rising temperature—reducing the temperature coefficient from –0.564 to –0.0575% K$^{-1}$. Stability evaluations revealed that the optimized cells retained more than 96% of initial efficiency after 2,280 hours of storage, 90% after 1,128 hours of heat aging, and over 92% after 1,088 hours of continuous illumination. These results highlight facet orientation as a direct and effective route to suppress non-radiative recombination, improve carrier mobility, and boost both efficiency and durability.

"Heat management has long been a bottleneck for PSCs," said corresponding author Prof. Qunwei Tang & Prof. Jialong Duan. "Our work demonstrates that by tailoring the crystallographic orientation of the perovskite film, we can simultaneously enhance efficiency and stability without relying solely on encapsulation. The (100) facet orientation not only facilitates faster heat dissipation but also reduces defect density, leading to more robust device operation. This approach provides a fundamental and scalable strategy for advancing perovskite photovoltaics toward real-world applications."

The ability to engineer perovskite films with self-cooling properties marks an important milestone for the commercialization of perovskite solar technology. Outdoor solar modules often operate under harsh thermal conditions, where even small efficiency losses accumulate into substantial performance declines. By integrating facet engineering, future perovskite modules can maintain power output in hot climates, extend operational lifetimes, and reduce maintenance costs. This thermal management strategy also opens possibilities for pairing perovskite devices with tandem architectures, where long-term durability is essential. Ultimately, the findings strengthen the competitiveness of perovskites as a next-generation photovoltaic technology.

References

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