

New insights to improve blade-coated perovskite films for scalable solar device

GA, UNITED STATES, November 26, 2025 /EINPresswire.com/ -- [Perovskite](#) thin films are key to high-efficiency and low-cost solar and optoelectronic devices. However, when produced at large scale, these films often suffer from uneven crystallization, defects, and instability, which reduce device performance and reliability. This study comprehensively analyzes the crucial factors that influence crystallization during blade-coating, a promising scalable fabrication method. It highlights how solvent selection, precursor concentration, additives, coating speed, substrate wettability, and ambient processing conditions collectively determine film microstructure and quality. By clarifying how these variables interact, the research provides systematic guidance for achieving uniform grain growth, dense film morphology, and reduced defect densities—offering a pathway toward highly efficient and commercially viable perovskite technologies.

Perovskite solar cells have rapidly achieved conversion efficiencies comparable to silicon, driven by their strong light absorption, long carrier diffusion, and tunable chemistry. To enable commercial deployment, however, scalable fabrication methods must produce films with high uniformity over large areas. Blade-coating has emerged as a leading candidate due to its simplicity, adaptability to continuous manufacturing, and high material utilization. Yet, in practice, blade-coated films often show variability in thickness, crystallinity, and defect density due to complex nucleation and growth dynamics. These inconsistencies hinder device output and long-term stability. Due to these challenges, there is a need to deeply investigate how processing parameters influence crystallization to guide large-scale production.

Researchers from Zhejiang University reported a comprehensive review in September 2025 in *Journal of Zhejiang University–Science A*, summarizing the key crystallization control mechanisms in blade-coated perovskite films. The work analyzes how solution chemistry, coating dynamics, environmental factors, and post-treatments collectively determine crystal nucleation, grain evolution, and defect distribution. By integrating recent advances, the study offers a clear framework to optimize film formation for scalable and reproducible device manufacturing.

The study identifies several interconnected factors that define crystallization behavior in blade-coated films. Solvent polarity and evaporation rate strongly influence supersaturation and nucleation timing, where mixed solvent systems help balance solubility and controlled crystal growth. Solution concentration and viscosity affect film thickness and uniformity, with overly high concentration leading to slow evaporation and defect formation, while excessively low concentration limits grain growth. Additives—such as ammonium salts, surfactants, and

coordination agents—fine-tune nucleation density, surface passivation, and interface quality, improving grain ordering and stability. Coating parameters, including blade speed, govern whether deposition occurs in evaporation-dominated or Landau-Levich regimes, which directly impacts crystal domain formation. Substrate wettability regulates liquid spreading and suppresses dewetting, while gas-quenching accelerates solvent removal to initiate uniform crystallization. Environmental factors, such as ambient humidity and oxygen exposure, modulate reaction pathways affecting film stability and phase purity. Together, these findings show that achieving high-quality films requires coordinated control of chemical composition, fluid dynamics, and atmospheric conditions during drying.

"The performance and stability of perovskite devices depend heavily on how the film crystallizes during deposition," the authors noted. "Understanding the interplay between solution chemistry, coating process, and environment allows us to systematically tune nucleation and grain growth. This is essential for producing uniform, defect-minimized films, particularly when scaling up from lab cells to large-area photovoltaic modules."

These insights provide a foundation for improving industrial perovskite solar module manufacturing. By optimizing crystallization pathways, manufacturers can achieve higher efficiency, better reproducibility, and longer device lifetimes. The framework also applies to perovskite light-emitting diodes, photodetectors, and tandem solar cells, where film quality is equally critical. Future advances may involve automated coating systems with real-time crystallization monitoring, eco-friendly solvent systems, and new passivation chemistries. Together, these developments could accelerate the commercial transition of perovskite technologies into mainstream clean energy and optoelectronic applications.

References

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Lucy Wang

BioDesign Research

[email us here](#)

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