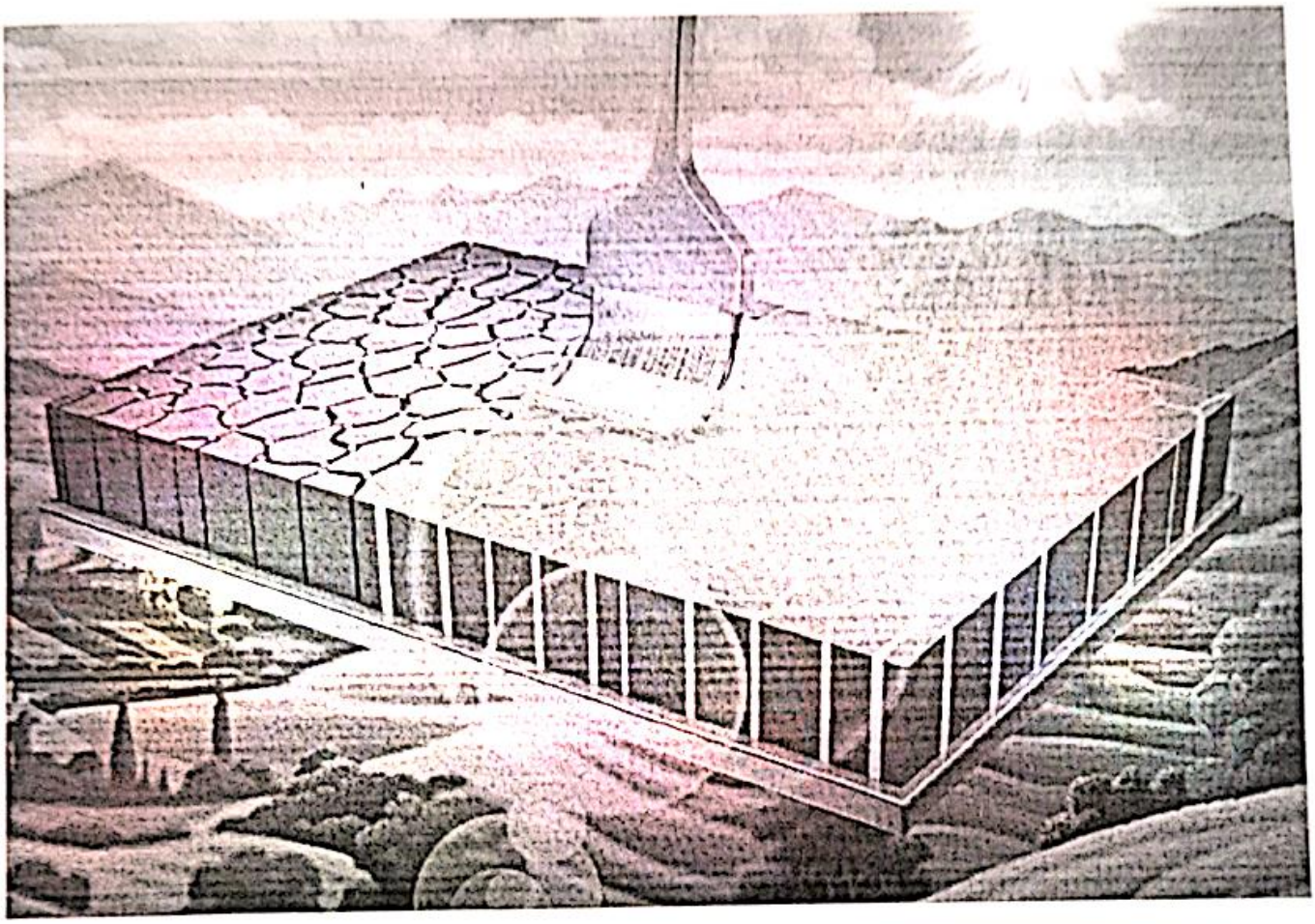
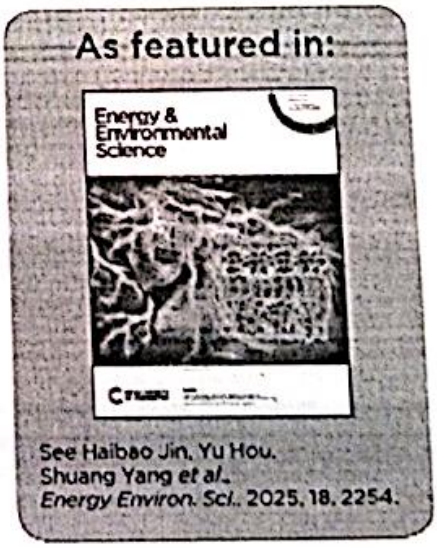


Showcasing research from Professor Shuang Yang, Yu Hou, and Haibao Jin's laboratories, School of Materials Science and Engineering, East China University of Science and Technology, Shanghai 200237, China.

Photomechanically accelerated degradation of perovskite solar cells

Understanding the origin of intrinsic instability for metal halide perovskites is indispensable for their advancement in opto-electronic applications. This paper investigates the impact of photomechanical effect on the stability of PSCs, and demonstrates a photomechanically accelerated degradation mechanism of perovskite thin films. This study shows that the physical separation of each perovskite grains using soft polymer can circumvent the photomechanical damage, and attain T97 of 1000 h under continuous one-sun illumination at 55 °C in solar cell devices.



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PAPER

View Article Online

Cite this: DOI: 10.1039/d4ee04878d

Photomechanically accelerated degradation of perovskite solar cells†

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Received 21st October 2024,
Accepted 2nd January 2025

DOI: 10.1039/d4ee04878d

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Understanding the origin of intrinsic instability of metal halide perovskites is indispensable for their advancement in opto-electronic applications. Here, we report a photomechanically accelerated degradation mechanism of perovskite thin films, in which the lattice expansion driven by light illumination has been found to govern the degradation kinetics. The dynamic lattice evolution under illumination causes crowding of the perovskite grains, leading to large local strains near the grain boundaries (GBs), which thereby facilitates defect formation and iodine component loss in the region. We show that the physical separation of each perovskite grain using trans-polyisoprene (TPI) could circumvent photomechanical damage at the GBs, achieving a T_{97} of 1000 h under continuous one-sun illumination at 55 °C in solar cell devices. Our results emphasize the nontrivial role of dynamic lattice deformation in the decomposition of perovskite thin films and open up new possibilities to further improve the intrinsic stability of solar cells.

Broader context

The certificated power conversion efficiency (PCE) of perovskite solar cells (PSCs) has surpassed 26%, yet their widespread application is still constrained by long-term reliability, particularly under light and thermal conditions. Softness is a fundamental characteristic of perovskite materials, which undergo remarkable dynamic structural evolution under environmental stress, such as light irradiation, temperature, and electrical fields. This can manifest in many unique dynamic properties, including giant photostriction, electrostriction, and large thermal expansivity. Here, we present the first study on the impact of the photomechanical effect on the stability of PSCs. We demonstrated a photomechanically accelerated degradation mechanism of perovskite thin films, where lattice expansion driven by light illumination governs the degradation kinetics. Experimental and theoretical studies revealed that perovskite grains accumulated strain at grain boundaries under illumination, which favored the formation of iodine-related defects and subsequent degradation. We further used soft polymers, such as TPI, to separate perovskite grains, stabilizing PSCs with 97.17% retained PCE after exposure to AM 1.5G irradiation and 35 °C illumination for 1000 h. We anticipate that the discovery of photomechanically accelerated degradation will open new avenues for designing long-lifetime PSCs for practical applications.

Introduction

Metal halide perovskites are regarded as the leading semiconductors for next-generation solid-state opto-electronics, having demonstrated unprecedented progress with over 26% certified efficiency in photovoltaic devices.[1–6] However, the widespread implementation of this technology is still challenged by its unsatisfactory long-term stability during operation under light illumination and thermal conditions.[7–13] Although progress has been made in recent years in stabilizing alternative components, such as charge transport layers and electrodes in photovoltaic devices, the perovskite layer itself still suffers from unsatisfactory intrinsic stability.[14–17] Before devising measures to enhance the photostability of perovskite solar cells (PSCs), it is crucial to understand the degradation mechanisms under

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† Electronic supplementary information (ESI) available. See DOI: https://doi.org/10.1039/d4ee04878d