

Materials Science and Engineering

Dissertation Defense

Engineering Film Stress for Mechanically and Operationally Stable Metal Halide Perovskites

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Abstract

Challenges to upscaling metal halide perovskites (MHPs) include mechanical film stresses that accelerate degradation, are more damaging with increasing module size, and can lead to delamination or fracture. In this work, we develop strategies to engineer and characterize film stress while linking it to degradation. By measuring the evolution of film stresses during accelerated aging conditions, we demonstrate for the first time that stress relaxation of >100 MPa occurs in MHP films with tensile stress that correlates with film degradation. Additionally, we map the film stresses from packaging using a displacement sensor to measure package curvature after lamination and use it as a metric for module reliability. Our studies found laminated MHP mini-modules with a “flat” front glass—and thereby experiencing a lower magnitude of film stress—retained 80% of their initial efficiency for twice as long as “curved” ones under accelerated light and heat testing. This discovery of a new mechanism underpinning MHP degradation shows that film stress can be used as a parameter to screen MHP devices and modules for quality control before deployment as a design for reliability criterion. We also demonstrate a facile route to a photostable mixed-halide perovskite thin film using a scalable deposition technique with a quench-free, open-air processing route using non-toxic additives. We show that these low-cost, polymer additives, namely, polyvinylpyrrolidone suppress photo-activated degradation products. These additives also create an amorphous protective layer over the perovskite promoting direct UVA-stability for up to 320 hours. We present this work as a scalable approach to control film stress that develop during processing, manufacturing, and operation and link these to changes to improve doperational stability of MHPs.

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