Studying Rapid Humidity Shifts during spin-coating on Perovskite Solar Cells

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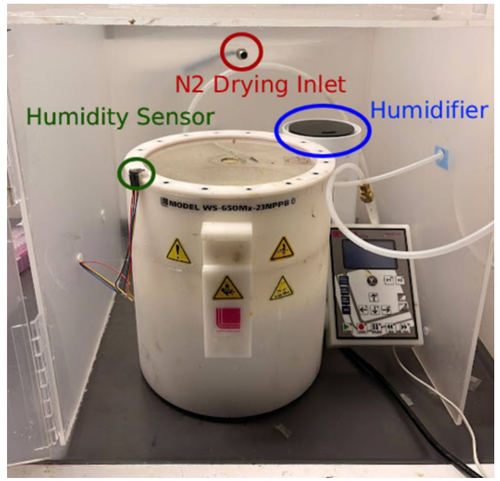
Introduction

Perovskite solar cells (PSCs) are highly sensitive to humidity during fabrication, as water influences nucleation and crystal growth. While controlled humidity can improve film formation, excess humidity can lead to degradation and non-uniform films[1]. Most studies focus on constant humidity conditions, whereas this work investigates how rapid humidity shifts during spin coating impact PSC formation

Process

An acrylic chamber was designed to control a small environmental space. Humidity was adjusted using an N_2 gas line and an internal humidifier, with real-time monitoring via an Arduino sensor system. MAPI w/ starch (open-air baseline) and MAPI w/ starch + PEG (humidity-mitigating additive) were tested under constant humidity, 30–40%, and 30–50% ramp conditions. Humidity ramps occurred relatively linearly over 35-40s of the 45s spin-coating process. This chamber was inspired by a similar environmental control setup developed by T Liu et al.[2]

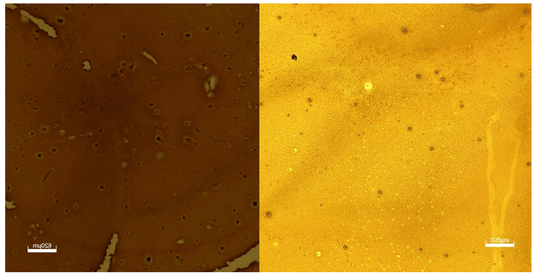


Custom humidity-controlled chamber with N_2 gas inlet, humidifier, and real-time humidity sensing.

Results

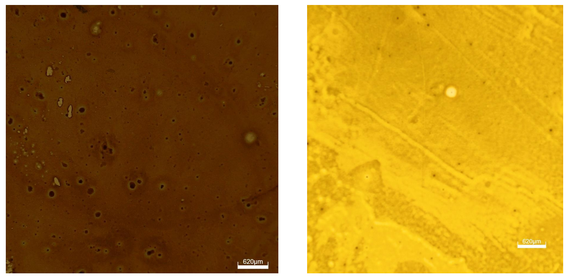
Samples with the highest photoactivity for each condition are shown in the microscope images, with corresponding RH vs. time profiles displayed below.

Constant(roughly ~26-30%RH)



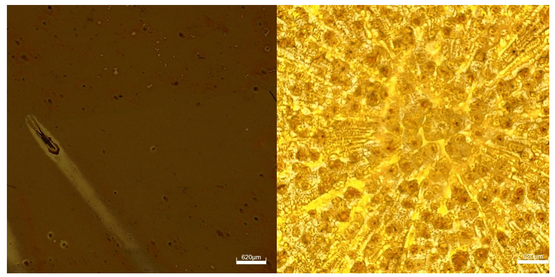
MAPI w/Starch | MAPI w/Starch & PEG

30-40% RH Ramp

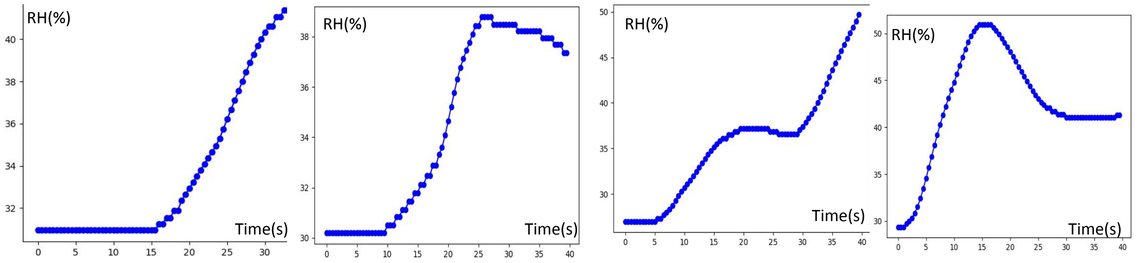


MAPI w/Starch | MAPI w/Starch & PEG

30-50% RH Ramp



MAPI w/Starch | MAPI w/Starch & PEG



Manual RH control caused overshoot, highlighting the need for future automatic control

Discussion

MAPI w/ starch showed minor variation across conditions, with only minor smoothing at 30-50% range. In contrast, MAPI w/starch + PEG films exhibited yellowing across all conditions, indicating degradation from the photoactive phase, and became increasingly rough with larger humidity ramps. This can suggest that higher humidity ramps may cause disorder in morphology, though future studies comparing rapidly changing RH samples with higher constant RH are needed for confirmation.

References:
1. Z. Lin et al., "Kinetics of moisture-induced phase transformation in inorganic halide perovskite," Matter, vol. 4, no. 7, pp. 2392–2402, Jul. 2021. doi:10.1016/j.matt.2021.04.023
2. T. Liu et al., "Disentangling the effects of simultaneous environmental variables on perovskite synthesis and device performance via Interpretable Machine Learning," arXiv.org, https://arxiv.org/abs/2509.09022 .

Grand Challenges Scholars Program

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