Supplementary information

The Importance of Moisture in Hybrid Lead Halide Perovskite Thin Film Fabrication

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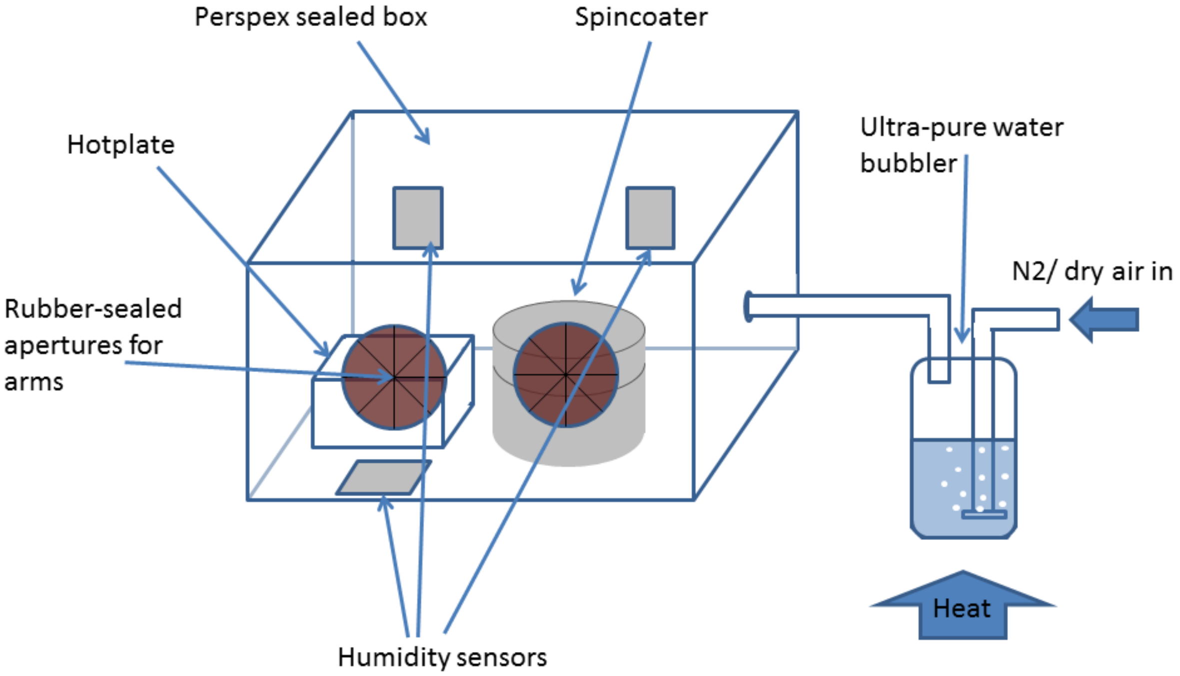


Fig. S1: Schematic of the humidity-controlled chamber, with spincoater and hotplate inside. Humidity and temperature are measured on 3 separate accurate humidity sensors and averaged for readings. For dry atmospheres, N2 or dry air is piped straight into the drybox without going through the bubbling system. To achieve very high humidities, we found it was necessary to heat the water bubbler to encourage evaporation. The chamber does allow some escape of gas through the arm-holes so does not build up pressure above room pressure.

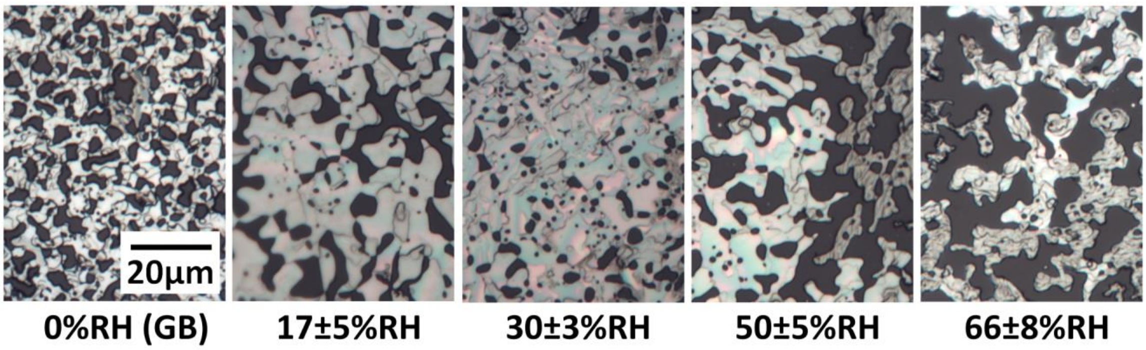


Fig. S2: Optical microscope images of perovskite films prepared on glass in a range of different humidities. Note that 0%RH is formed in a nitrogen-filled glovebox using a different spin-coater, which likely explains the different appearance.

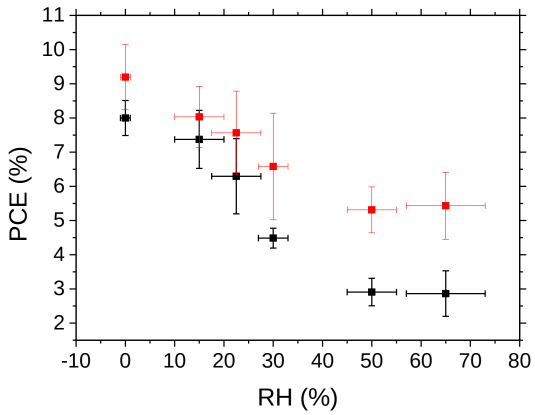
	J_{sc} ($mAcm^{-2}$)	PCE from fast scan (%)	V_{oc} (V)	FF	SPO (%)
Dry MAI in 0% RH / SWCNT-HTL	17.7±0.9	8.5±1.2	0.87±0.02	0.54±0.04	5.7±0.2
Dry MAI in 0% RH/ Spiro-OMeTAD	17.5±1.5	11.7±1.5	0.98±0.05	0.67±0.03	7.2±2.1
Standard MAI in 0% RHF/ SWCNT-HTL	20.2±1.8	11.8±1.8	0.99±0.03	0.58±0.05	6.5±0.7*
Dry MAI in 30% RH / SWCNT-HTL	16.0±1.5	8.7±1.6	0.95±0.03	0.56±0.05	4.0±0.3

*this stabilised power output measurement was taken from a different set of cells with similar performance.

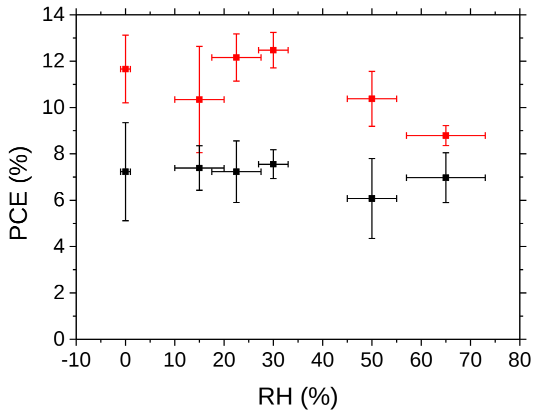
Table S1: Average device performance data from at least 14 devices with perovskite films prepared with and without possible exposure to moisture in different ways – via exposure in the MAI, exposure during Spiro-OMeTAD doping, and exposure during annealing. SPO measurements taken from at least 4 stabilised devices.

	J_{sc} ($mAcm^{-2}$)	PCE from fast scan (%)	V_{oc} (V)	FF	SPO (%)
0%RH anneal	18.3±0.5	9.0±1.4	0.87±0.04	0.56±0.06	5.8±1.3
Oxygen anneal (0%RH)	17.6±1.1	8.6±1.2	0.87±0.03	0.56±0.04	4.6±0.23

Table S2: Average device performance data from at least 14 devices with perovskite films prepared with and without annealing in pure oxygen or nitrogen. SPO measurements taken from at least 4 stabilised devices.

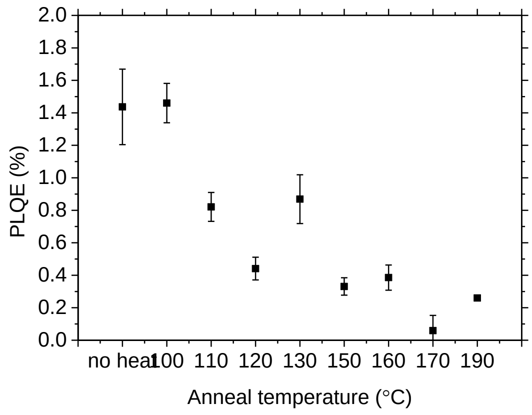


a)

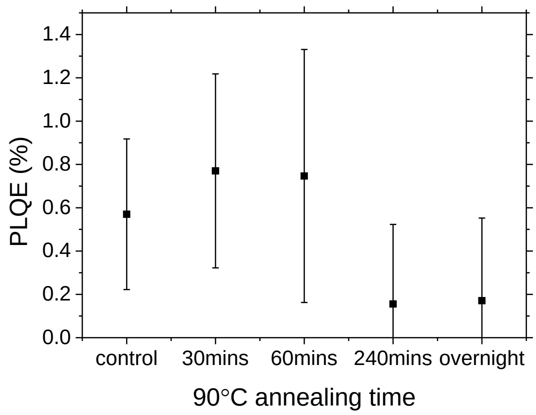


b)

Fig. S3. Average device data for spiro-OMeTAD-based perovskite solar cells fabricated at different humidity levels. We show stabilised power output (SPO) (black) and fast JV-scanned PCE (red) a) for planar perovskite devices and b) for mesosuperstructured alumina-based devices. Error bars are given by standard deviation; each point for the fast JV PCEs represents at least 15 devices and for the SPO measurement at least 6 devices were held until steady-state efficiency was reached.



a)



b)

Fig. S4. Investigation of whether further annealing can increase PLQE, replacing water treatment. a) PLQE as a function of temperature for a 15-minute post-anneal in nitrogen atmosphere. b) PLQE as a function of annealing time at 90°C. We observe that neither increasing the annealing time nor the annealing temperature can increase PLQE in the same way as the moisture treatments.

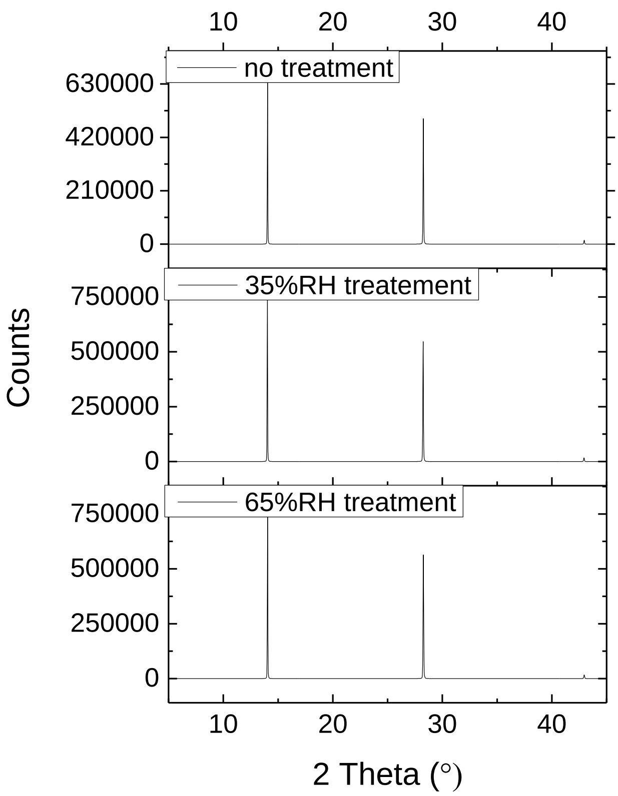


Fig. S5. XRD spectra for films fabricated fully in nitrogen (0%RH) and post-treated at 35%RH for 4h at room temperature, or at 65%RH for 30 minutes at 90°C. The control film is never exposed to moisture.

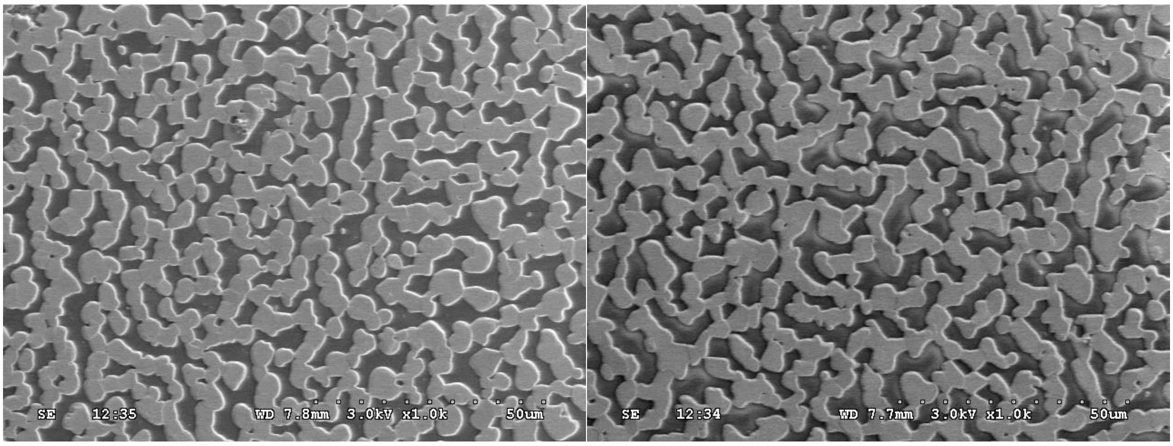


Fig. S6: Morphology after moisture treating perovskite films with 35%RH for 4h. Untreated films are on the left, and treated films on the right.

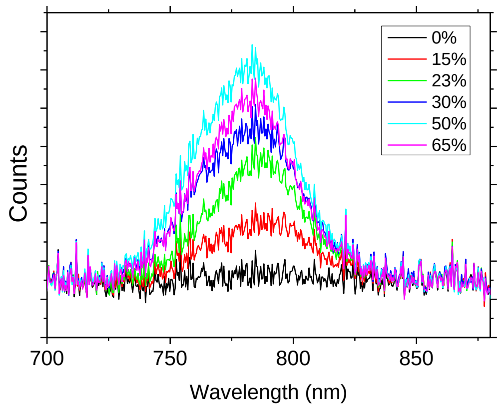


Fig. S7. PL spectra for films annealed in different levels of humidity.

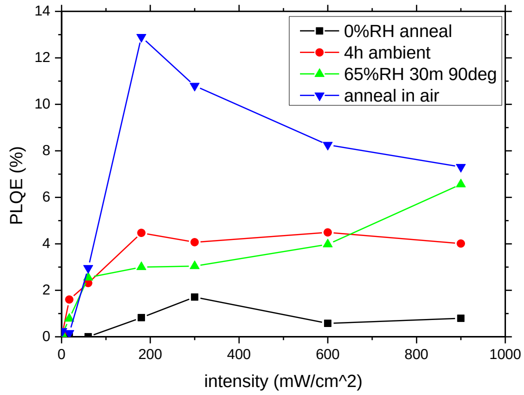


Fig. S8. PLQE intensity dependence for untreated and moisture-treated perovskite films.