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## Operando study of humidity on the performance of perovskite solar cells

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Perovskite solar cells (PSCs) are among the most promising photovoltaic technologies and reached a certified 25.6% efficiency owing to their tuneable bandgap, high charge carrier mobility, long diffusion length. The long-term operational stability of PSCs, however, has been not investigated in depth. Herein, we probe the structure changes with grazing-incidence small-angle x-ray scattering techniques (GISAXS) under high humidity conditions. Also, the solar cell parameters are obtained simultaneously during the device operation. We find that PSCs fabricated with and without caesium iodide (CsI) show differences in the device degradation and morphology change in the perovskite layer. The decrease of open-circuit voltage (VOC) can be attributed to the morphology changes and the evolution of crystallize grain size. With the additive of CsI, solar cells show a slow decay of VOC, which is correlated to an improved morphology of the active layer and a passivation of trap states. Our work presents a crucial step towards a fundamental understanding of morphology changes being probed combined with solar cell parameters during the device operation.

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