A machine vision tool for facilitating the optimization of large-area perovskite photovoltaics

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A bottleneck to deposit homogeneous large-area perovskite films is the inability to quickly quantify the homogeneity of these films. Standard stylus profilometry measurement is destructive, and the acquisition time scales with device area and thus goes up dramatically when working on large samples. Once perovskite films are integrated into devices, techniques such as electroluminescence and light-beam-induced current can provide spatially resolved information. However, device preparation is time-consuming, and the performance of a full device may be limited by other layers inhomogeneities. Therefore, researchers often evaluate the perovskite film homogeneity prior to device fabrication by either cutting large-area substrates into smaller pieces for individual characterization, or by relying on visual inspection alone. Here, we combine fast optical imaging (~ 10 s / sample) with machine vision to obtain a reliable and non-destructive method for quantifying the homogeneity of perovskite films. We adapt existing algorithms to spatially quantify multiple perovskite film properties (substrate coverage, film thickness, defect density) with 10 µm x 10 µm pixel resolution from pictures of 25 cm² samples. Our machine vision tool - called PerovskiteVision - can be combined with an optical model to predict photovoltaic cell and module current density from the perovskite film thickness. We use the extracted film properties and predicted device current density to identify a posteriori the process conditions that simultaneously maximize the device performance and the manufacturing throughput for a large-area perovskite deposition process (gas-knife assisted slot-die coating). PerovskiteVision thus facilitates the transfer of a new deposition process to large-scale photovoltaic module manufacturing. This work shows how machine vision can accelerate slow characterization steps essential for the multi-objective optimization of thin film deposition processes.