

## Recycling Perovskite Solar Cell by Novel Spray Processes

Perovskite solar cells have had rapid growth in their performance and efficiency over just a few years. To achieve high performance, the perovskite absorbers require high crystallinity and good surface morphology. However, the solar cells still ends up as wastes at the end of their life time. The problem is exacerbated by the solar cells' relatively poor stability where perovskite materials ( $\text{CH}_3\text{NH}_3\text{PbI}_3$ ) can be degraded to  $\text{PbI}_2$  waste films with heat, humidity, or UV exposure. Boonthum et al developed a technique called repeated cation doping as a recycling process to convert  $\text{PbI}_2$  waste films back to perovskite thin films. Further efforts were done to improve  $\text{PbI}_2$  waste films prior to the recycling process by spinning low concentration solutions of  $\text{PbI}_2$  on top of the waste films to fill in pinholes on the  $\text{PbI}_2$  layers, which cause low device performance. The spinning process however has scale-up limitations and is uneconomical as a large portion of the solution is spun off as excess. In this study, a novel spray process was employed to fill in pinholes on  $\text{PbI}_2$  waste films. Furthermore, repeated cation doping was further improved, basing on spray process. Spray times, concentrations and annealing parameters were varied to determine the optimal conditions. The newly developed spray processes for recycling enable better film performance and economical uses of materials with scale-up potential.

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