Effect of Anti-Solvent Treatment on Fabrication of Large Area Perovskite Solar Cells

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Recently, hybrid organic-inorganic perovskite solar cells have attracted much attention, as its power conversion efficiency (PCE) has leapt from 3.8% in 2009 to the current world record of 22.1%. This is attributed to its excellent photoelectronic properties such as a remarkably high absorption coefficient; a low exciton binding energy; a carrier diffusion length in the micrometer range, caused by recombination occurring on a timescale of hundreds of nanoseconds; and a tunable energy bandgap. Because of on these properties, the perovskite materials are suitable as light absorbers in the field of solar cells as well light-emitting devices. However, the surface coverage and morphology of perovskite film are controlled by the nucleation rate and the grain growth rate. To solve this problem, this work explores various anti-solvent treatments for the perovskite film. Let the anti-solvent drives the perovskite precursor into the metastable zone or the supersaturation zone. Here, we make a systematic study of different types of anti-solvents including toluene (TL), chloroform (CF), chlorobenzene (CB), dichlorobenzene (DCB), isopropyl alcohol (IPA). We found that an anti-solvent with a low dielectric constant (<5) and low dipole moment (<1) is most the suitable for perovskite solar cell preparation, such as toluene. Therefore, selection of the anti-solvent is an important factor when fabricating high-performance perovskite solar cells. Furthermore, we found that mixed two anti-solvents, can get more driving force to let the perovskite precursor into the metastable zone. We can fabricate high crystal, high coverage and smooth perovskite film to make perovskite solar cell by mixed anti-solvents treatment. It can improve the fill factor of perovskite solar cell. We use TL/DCB(v/v=5/5) as anti-solvent, can let the n-i-p type perovskite solar cell toward 18.01%(AM1.5G, 100mW/cm^2). On the other hand, there are the same effects of mixed anti-solvent in p-i-n type perovskite solar cell. In p-i-n perovskite solar cell, we add 0.1wt% PCBM in TL/DCB. It can fill the grain boundary in perovskite film, increase the electron collection, and improve the fill factor and current density. After optimization process, the efficiency can toward 16.31% from 15.37% (AM1.5G, 100 mW/cm^2).

Finally, we use the optimized anti-solvent condition combine the 5cm×5cm perovskite module pattern designed by our lab (active area 10.56 cm^2). For n-i-p type perovskite sub-module, the efficiency is about 14.56% (AM1.5G, 100 mW/cm^2). For p-i-n type perovskite sub-module, the efficiency is about 15.02% (AM1.5G, 100 mW/cm^2).