

## Realization of Nozzle-Jet Printing Technique for Perovskite Solar Cells

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The rapid rise in the efficiency of perovskite solar cells (PSCs) using a mixed-halide organolead compound has received much attention in recent years for high energy conversion. In this study, we present a novel printing technique, named nozzle-jet printing (NJP), which is capable of achieving a compact  $\text{TiO}_2$  (C- $\text{TiO}_2$ ), mesoporous  $\text{TiO}_2$  (MP- $\text{TiO}_2$ ) and  $\text{CH}_3\text{NH}_3\text{PbI}_3$  (MAPbI<sub>3</sub>) layer under ambient conditions. With the combined optimization of printing parameters and ink compositions, C- $\text{TiO}_2$ , MP- $\text{TiO}_2$  and MAPbI<sub>3</sub> patterns with favorable morphology and high uniformity are realized. Besides, we found that the temperature of the substrate plays an important role to achieve uniform morphology and high crystallinity of MAPbI<sub>3</sub> patterns during the printing process. Compared to the conventional method spin-coating, when such printed patterns (C- $\text{TiO}_2$ /MP- $\text{TiO}_2$ /MAPbI<sub>3</sub>) are embedded in PSCs, we obtain a better performance of power conversion efficiency (PCE), open-circuit voltage (Voc), short-circuit photocurrent density (Jsc) and fill factor (FF) of up to 5.89%, 0.72 V, 15.11 A and 54.10% in air condition with a humidity of 40%. These results indicate that the NJP technique has the potential to complete each layer in different types of solar cells.