

Innovative PIN-type perovskite solar cells with 17 % efficiency: processing and characterization

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Supporting Information

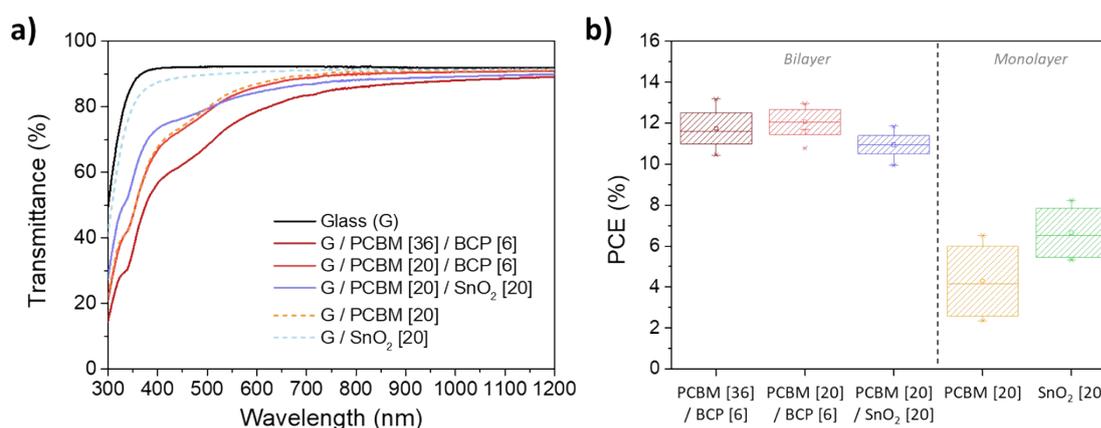


Figure S1: a) UV-Vis spectra of different N-layers tested; b) Performance of solar cells obtained with different N-layers. (the numbers in square brackets indicate the thickness of the layers in nm)

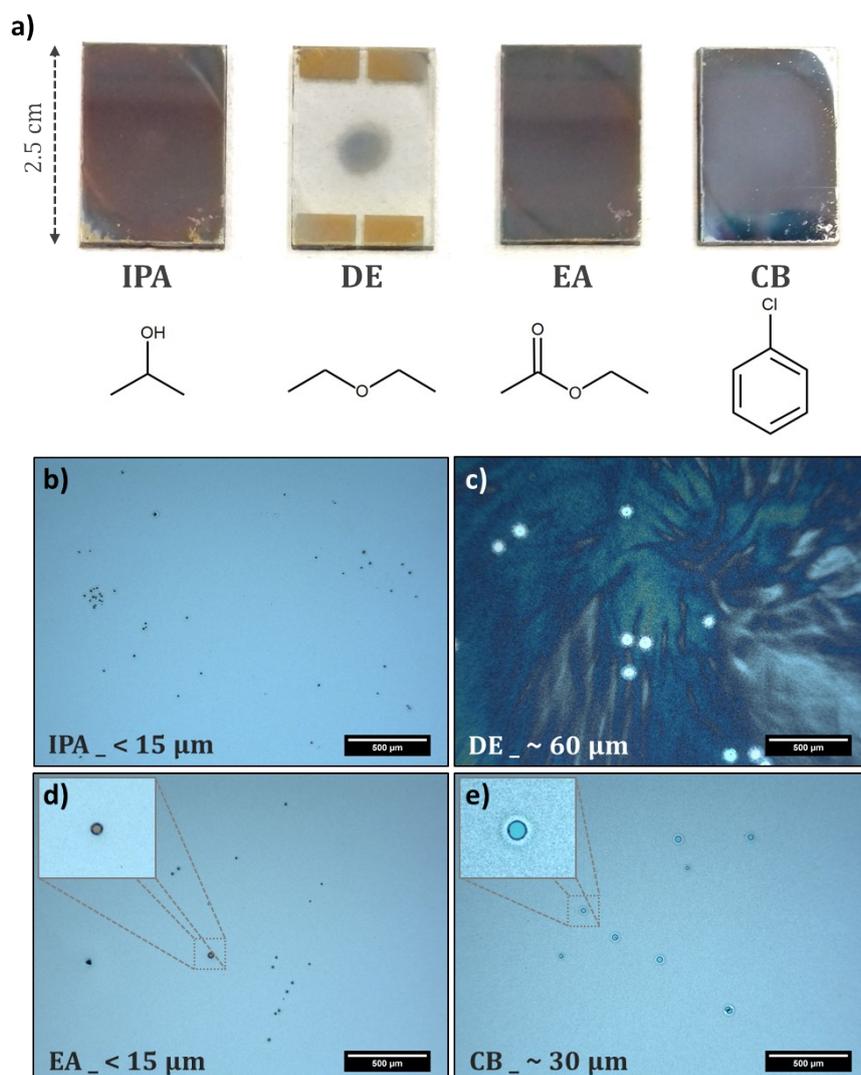


Figure S2: (a) Photographs of typical perovskite layers deposited on PTAA and obtained with the different selected anti-solvents; Optical microscopy images in reflection mode of the surface of perovskite layers deposited with the following anti-solvents: (b) IPA, (c) DE, (d) EA and (e) CB. The characteristic diameter of the holes is displayed at the bottom right of the corresponding image. An enlargement in the case of EA and CB shows a different color inside their holes indicating the persistence of PTAA after use of EA.

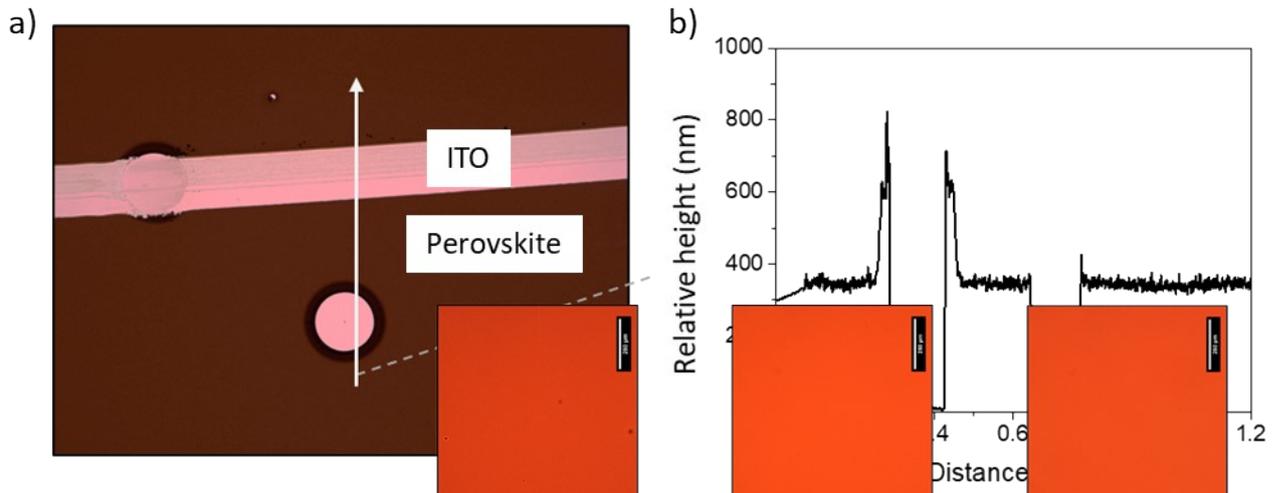


Figure S3: a) Micrograph of a perovskite layer on an ITO substrate. The arrow indicates the direction of the AFM profile measurement. b) AFM height profile showing relative height (nm) on the y-axis and distance on the x-axis. The profile shows a sharp peak reaching approximately 800 nm.

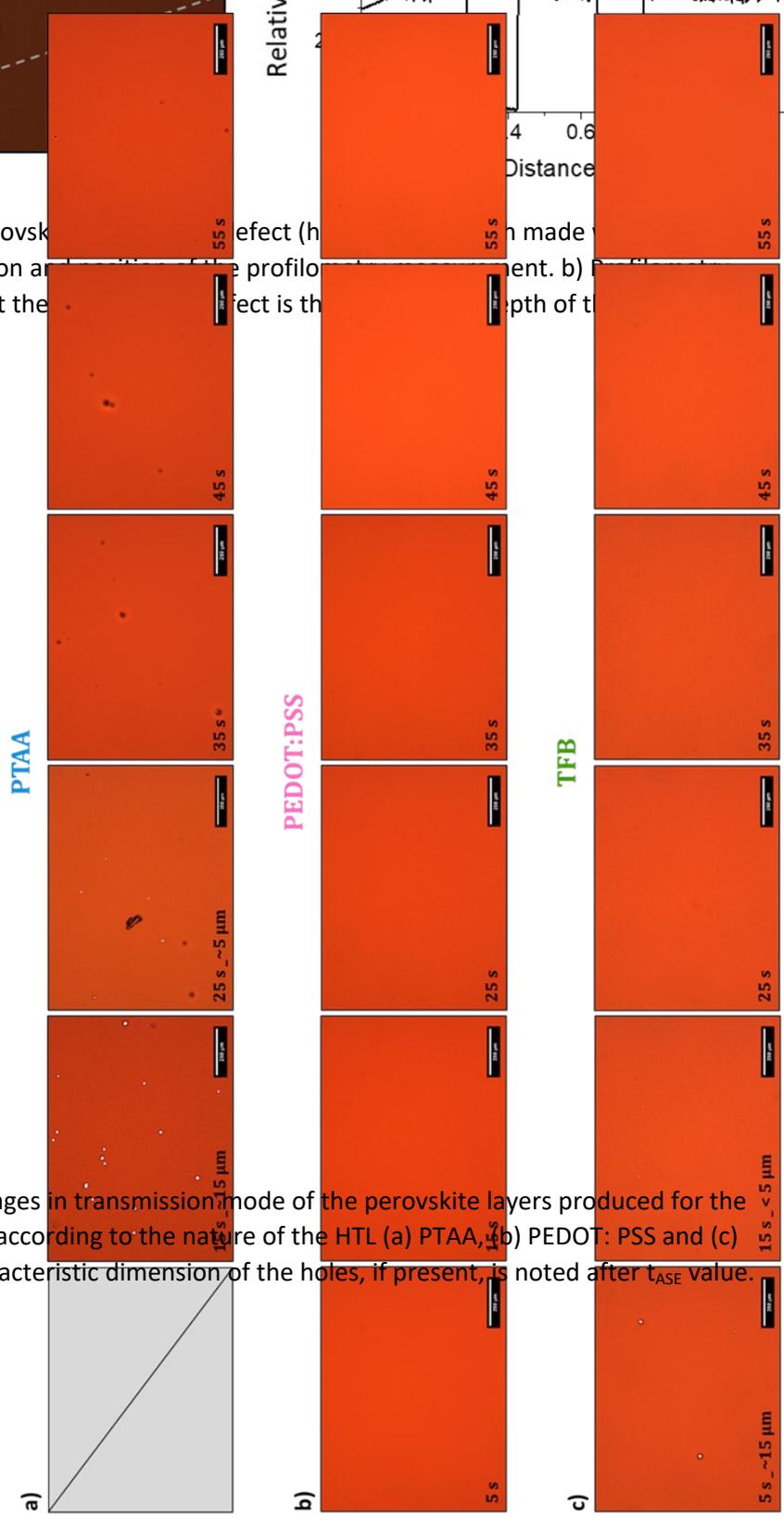


Figure S4: Optical microscopy images in transmission mode of the perovskite layers produced for the different t_{ASE} (AE as anti-solvent) according to the nature of the HTL (a) PTAA, (b) PEDOT: PSS and (c) TFB (scale bar: 250 μm). The characteristic dimension of the holes, if present, is noted after t_{ASE} value.

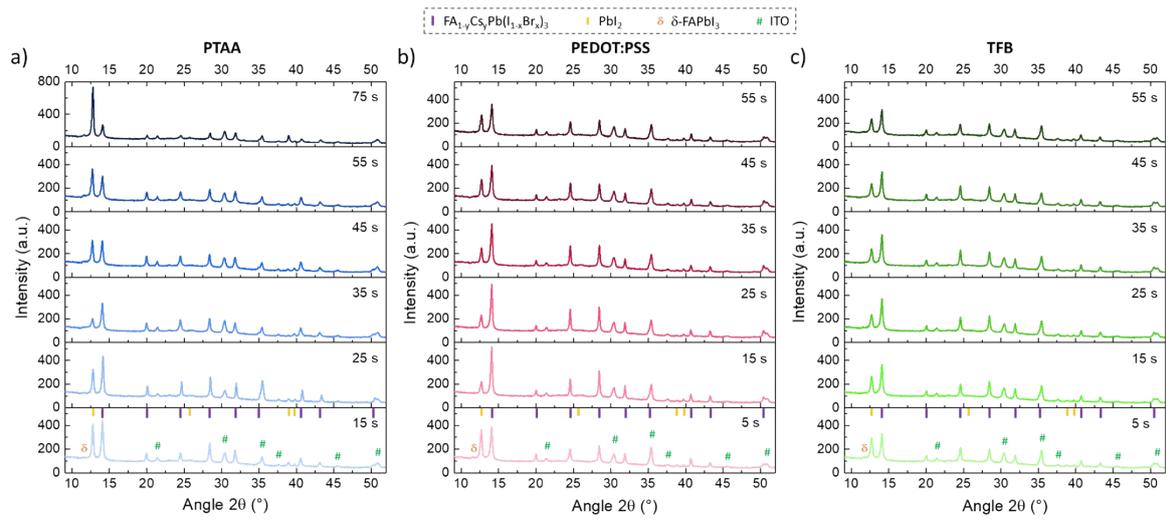


Figure S5: X-ray diffractograms of the perovskite layers produced for different t_{ASE} in the case of (a) PTAA (in blue), (b) PEDOT:PSS (in red) and (c) TFB (in green). In addition to the diffraction peaks corresponding to ITO, three main crystal phases are detected: $FACsPbI_3Br$, PbI_2 and δ -FAPbI₃.

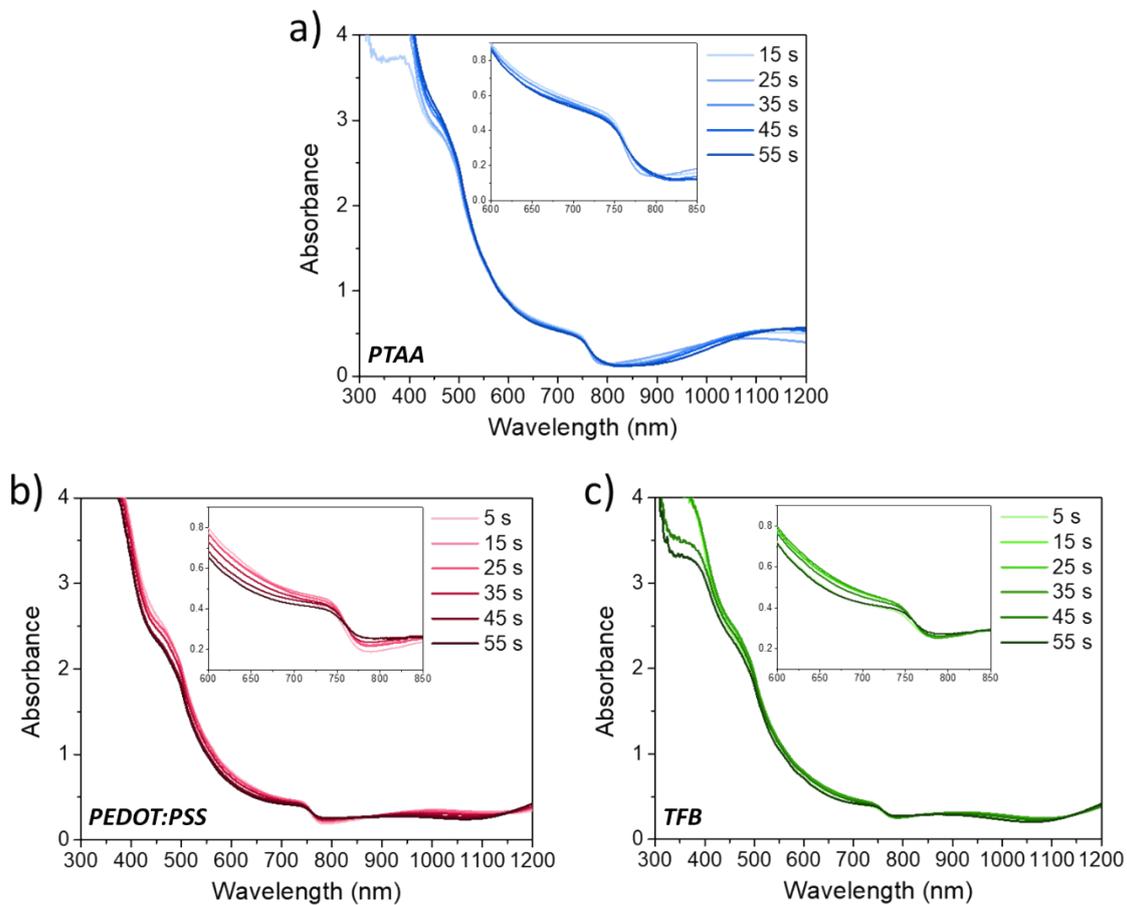


Figure S6: Absorbance spectra of the perovskite layers obtained for the different t_{ASE} studied in the case of (a) PTAA (in blue), (b) PEDOT:PSS (in red) and (c) of TFB (in green). An enlargement of the absorption threshold of FACsPbI₃Br perovskite is also inserted.

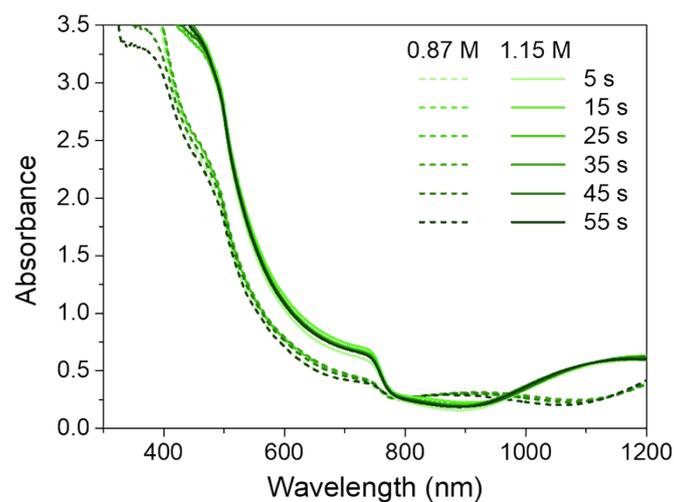


Figure S7: UV-Vis spectra of perovskite layer for the two precursor concentrations (0.87 mol.L⁻¹ and 1.15 mol.L⁻¹) and for variable ejection times.

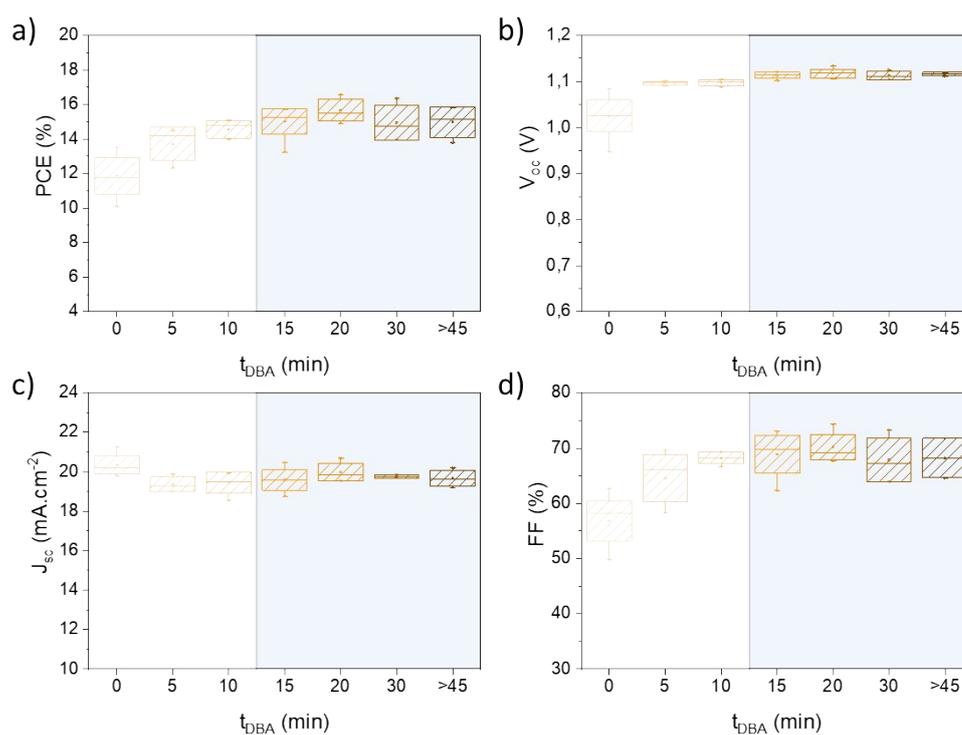


Figure S8: Means (points), medians (lines) and standard deviations (boxes) of (a) PCE, (b) V_{oc} , (c) J_{sc} and (d) FF from J-V measurements of perovskite devices as a function of t_{DBA} (exemple for $t_{ASE} = 35$ s).

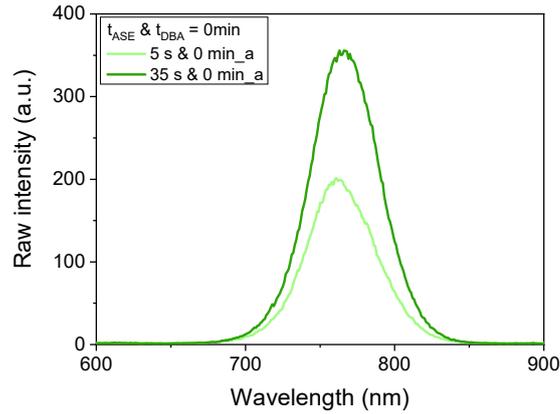


Figure S9: PL spectra of perovskite layer for $t_{ASE} = 5s$ and $35s$ (for $t_{DBA} = 0$ min)

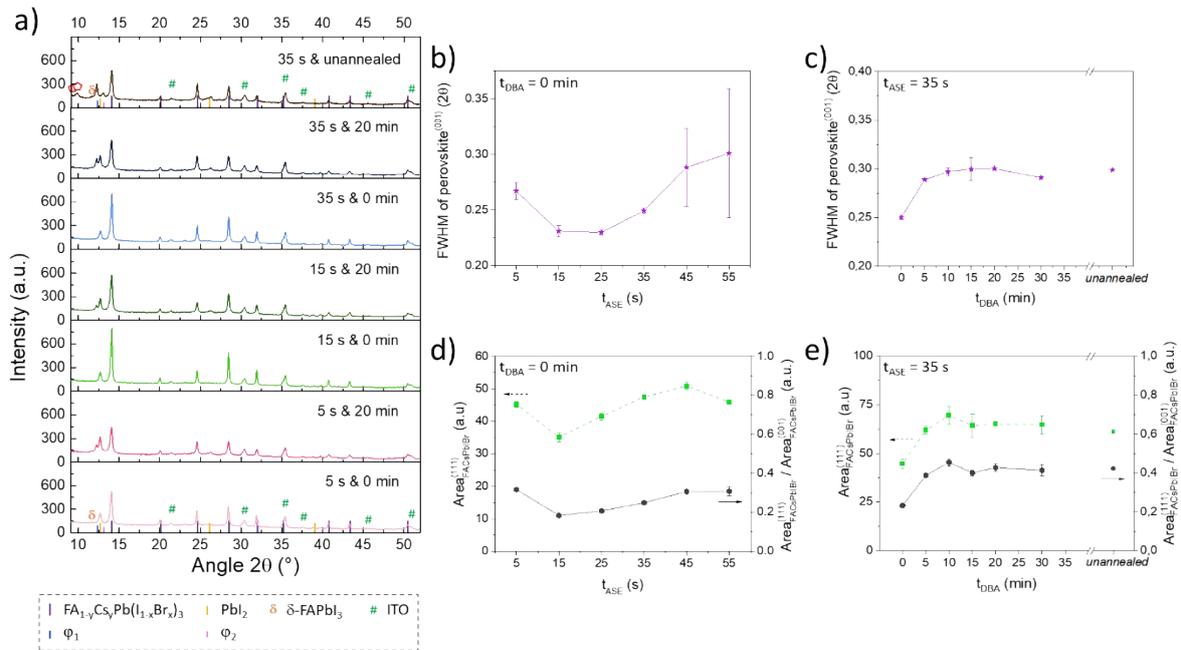


Figure S10: a) Compilation of X-ray diffractograms of the perovskite layers (in half-cells) produced by varying t_{ASE} and t_{DBA} ; b-c) Full width at half maximum of the main diffraction peak (001) of the perovskite phase according respectively to t_{ASE} and t_{DBA} variations; d-e) Extracted area of the perovskite diffraction peaks attributed to (111) orientation and ratio of FACSPbBr orientations ((111) divided by (001)) as a function of both t_{ASE} and t_{DBA} variations.

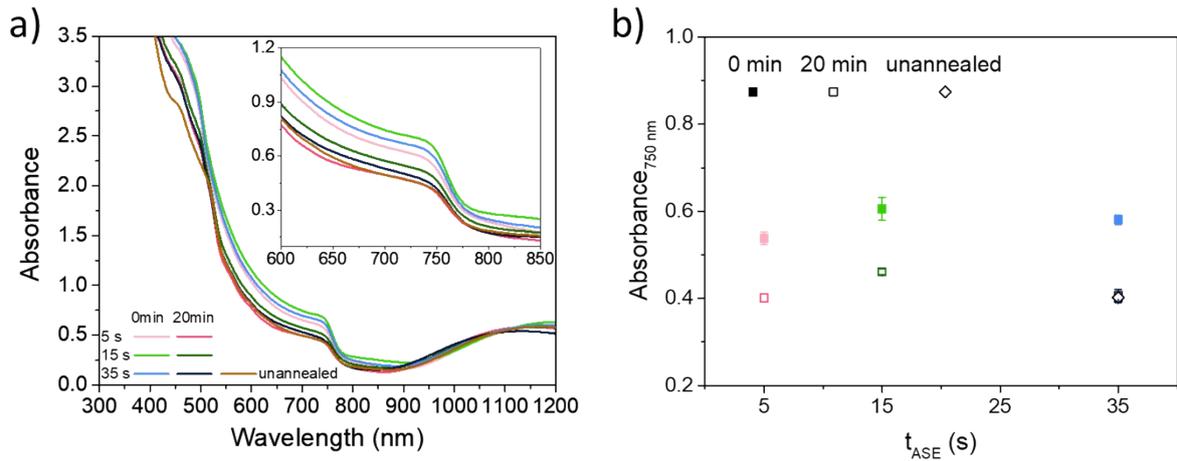


Figure S11: a) Absorption spectra and b) Absorbance value at 750 nm of perovskite layers for different conditions of t_{ASE} and t_{DBA} .

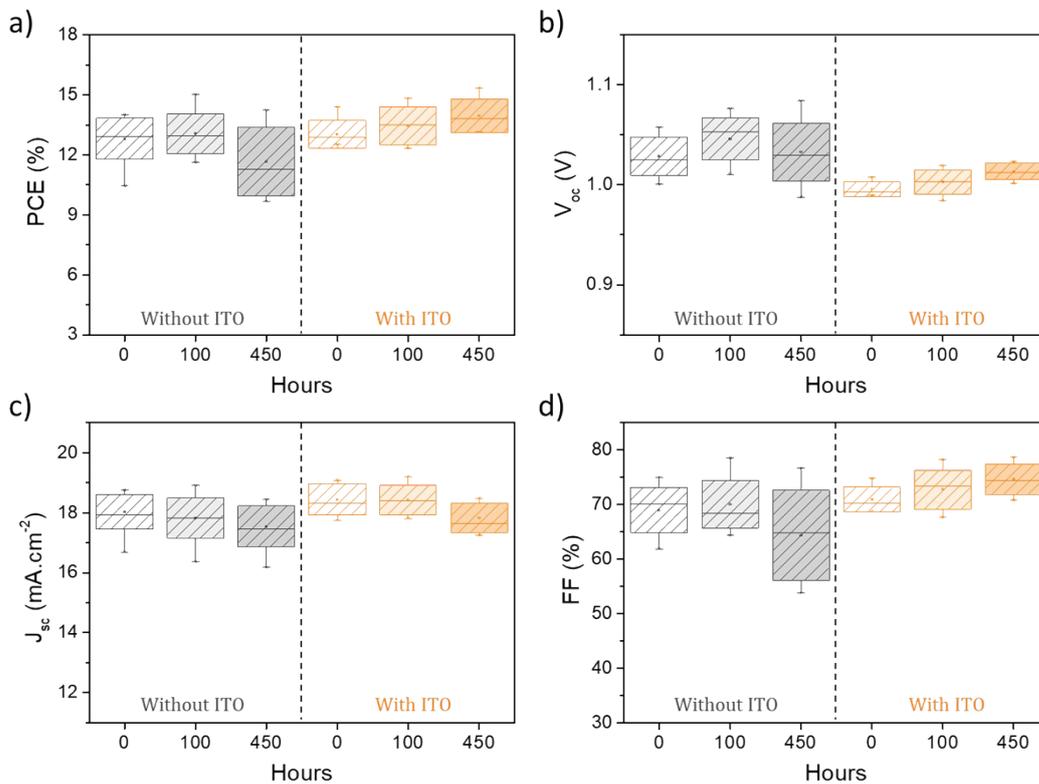


Figure S12: Stability study of typical solar cell developed in this article (Without ITO) compared to similar solar cells with an additional layer based on sputtered ITO (With ITO): Monitoring of PV parameters during a 450h aging in the dark in a glove box, at room temperature.

A small stability study was indeed conducted in a glovebox, in the dark, and at room temperature. The cells corresponding to those studied in the publication are those noted "without ITO". These cells are not perfectly stable, probably because of the N layer which is not a barrier to the silver electrode. Indeed some articles in the literature mention the diffusion of silver through SnO₂ nanoparticles, PCBM and perovskite. However, by inserting a layer of sputtered ITO between the SnO₂ and the silver electrode (in

order to make cells in semi-transparent configuration, which will be the subject of another future paper), the devices (noted “with ITO”) are more stable in time, which shows that the perovskite layer does not age intrinsically. Thus, the intermediate phases formed during the drying phase have no impact on the stability of the perovskite layer.

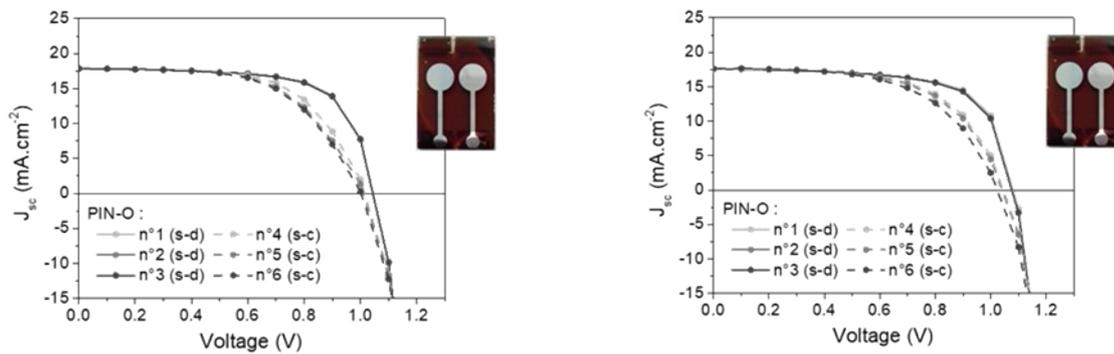


Figure S13: J-V curves measured successively from n°1 to n°6 with 1 min interval for a cell similar to the study (the first three curves being in the decreasing direction in solid line and the last three in the increasing direction in dotted line), before (left) and after (right) aging.