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Supplementary Information

Solution-processed CuBO₂ hole transport layers for stable p-i-n perovskite solar cells

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Fig. S1 SEM images of CuBO₂ films obtained under different precursor concentration: (a) 0.1 M, (b) 0.2 M, (c) 0.3 M, and (d) 0.4 M.



Fig. S2 SEM images of $CuBO_2$ films obtained under different precursor pH values: (a)

0.5, (b) 1.75, and (c) 2.75.



Fig. S3 Digital photos of precursors and samples calcined at different temperatures.



Fig. S4 TEM image of CuBO₂ nanocrystals.



Fig. S5 (a) EDX spectrum and (b) EDX mapping of CuBO₂.



Fig. S6 (a) XPS full spectrum of CuBO₂, (b) XPS spectrum of Cu 2p, (c-f) core energy level spectra corresponding to Cu $2p_{3/2}$, Cu $2p_{1/2}$, B 1s, O 1s, respectively.



Fig. S7 Mott-Schottky plot of $CuBO_2$ film measured in three-electrodes system.



Fig. S8 Box plots of photovoltaic parameters of $CuBO_2$ and PEDOT:PSS-based PSCs (20 devices in each group).



Fig. S9 J-V curves of PSCs with an area of 1.08 cm^2 based on CuBO_2 and PEDOT:PSS HTLs and the inset shows the digital photograph and performance parameters.



Fig. S10 Box plots of $CuBO_2$ and PEDOT:PSS-based PSCs with an area of 1.08 cm² (20 devices in each group).



Fig. S11 UV-vis absorption spectra of perovskite films based on different HTLs.



Fig. S12 IPCE curves and integrated J_{SC} of PSCs based on different HTLs.



Fig. S13 Dark current-voltage curve of hole-only devices.



Fig. S14 Nyquist plots of PSCs based on $CuBO_2$ and PEDOT:PSS HTLs.



Fig. S15 (a) J_{SC} and (b) V_{OC} versus light intensity for the devices based on the different HTLs.



Fig. S16 Photostability of devices based on different HTLs without encapsulation.



Fig. S17 Wet-heat stability test of unpackaged PSCs with natural day-and-night cycle at about 85% RH and 85°C.