

Supplementary Information

Back-Contacted Hybrid Organic-Inorganic Perovskite Solar Cells

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Experimental Section

Electrode Fabrication: Pre-patterned indium tin oxide (ITO) substrates were cleaned with acetone and isopropanol prior to the sputtering of a ~50 nm ZnO layer.¹ A thin layer (~2 μm) of photoresist was deposited via spin coating on the substrates with subsequent baking at 110 °C for 2 min. The substrates were exposed to UV radiation through a photomask and the desired features on the photoresist were achieved by immersing the substrates into a developer bath for 40 sec. Then, layers of Al₂O₃ (100 nm), Al (30 nm) and Ni (50 nm) were deposited onto the substrates using an electron beam evaporator. Finally, the substrates were washed with acetone to remove the rest of the photoresist (lift-off process).

Solar Cell Fabrication: The electrodes were annealed at 300 °C in ambient atmosphere for 15 min prior to the deposition of a CH₃NH₃PbI₃ absorber layer. The absorber layer was then deposited using a method described by Huang et al.² A precursor solution used for the CH₃NH₃PbI₃ absorber layer consists of a 1:1 molar ratio of PbI₂ and methyl ammonium iodide (MAI) in *N,N*-dimethylformamide (DMF).

Device Characterization: The work functions of different surfaces were investigated using a Riken Photoelectron Spectrometer (Model AC-2) at 15 nW. The thickness of the samples was measured with a Veeco Dektak 6M profilometer. Solar cell cross-section images were obtained using a Zeiss Merlin scanning electron microscope (SEM) operated at 5 kV and 120 pA. The *J-V* characteristics of the devices were measured in an inert atmosphere with a computer-controlled Keithley 2400 Sourcemeter. A 150 W Xenon lamp (Newport) coupled with an AM 1.5G solar spectrum filter was used as the light source. Light was illuminated through a quartz window of the glove box and the intensity was calibrated and monitored using a secondary reference photodiode (Hamamatsu S1133, with KG-5 filter, 2.8 × 2.4 mm of photosensitive area), which was calibrated by a certified reference cell (PVMeasurements, certified by NREL) under 1000 W m⁻² AM 1.5G illumination from an Oriel AAA solar simulator fitted with a 1000 W Xenon lamp. Devices were measured at the same position as the secondary reference cell. The photocurrent (PC) and photoluminescence (PL) mapping was measured with a custom built setup based on modified WiTec Alpha 300R confocal Raman/PL microscope operating in reflection mode. A Nd:YAG diode laser with a wavelength of 532 nm (laser power, ~10 nW) chopped with a C995 (Terahertz Technologies Inc.) optical chopper with a frequency of 572 Hz was employed for excitation. The PL and current signal were detected by an air cooled CCD detector and a FEMTO LIA-MV-150 lock-in amplifier. Amplifier settings were chosen accordingly to achieve synchronous detection of both PL and PC signal. The bias was applied with the preamplifier. To acquire two-dimensional spectral mapping, the device under test (DUT) was moved with the X-Y piezo stage of the microscope.³

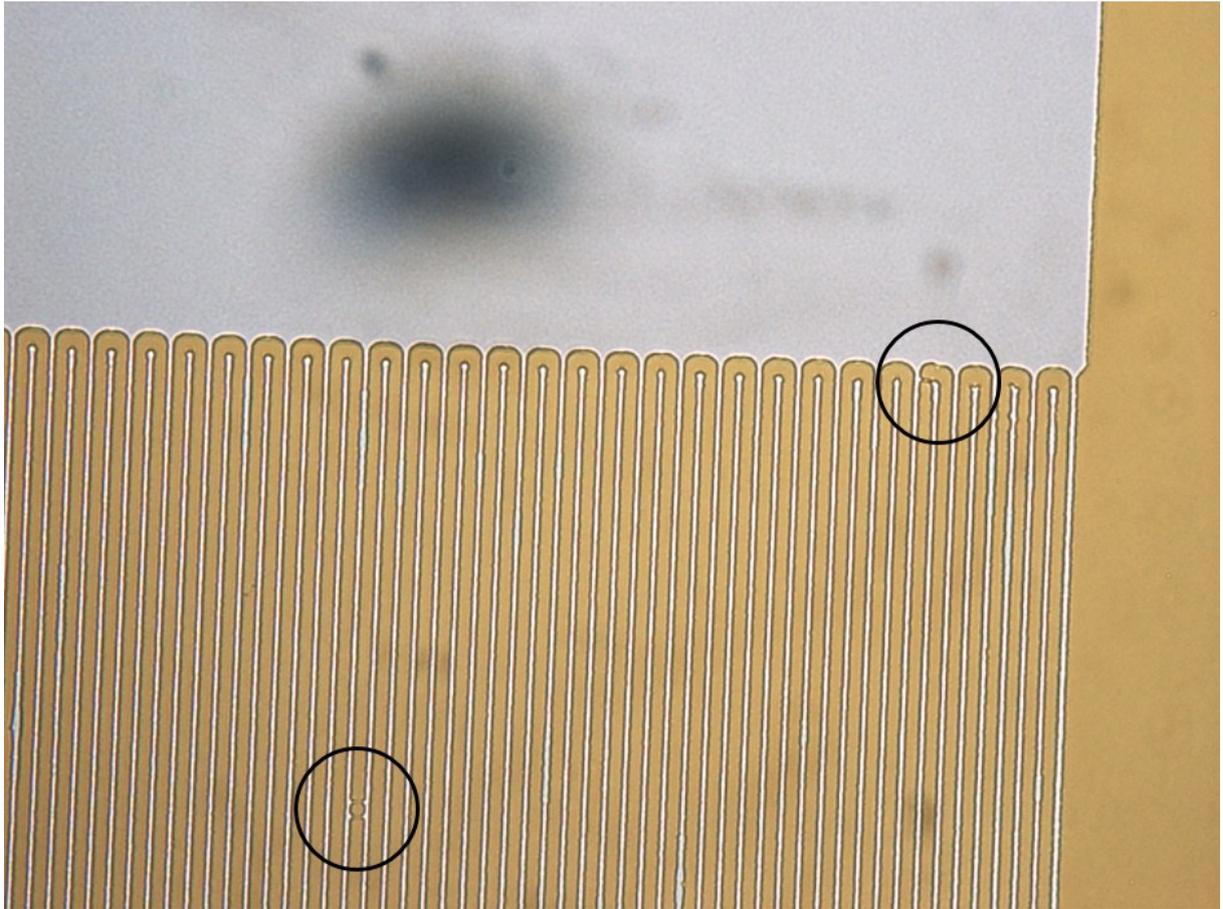


Fig. S1 Optical microscope image of an IDE ITO on a glass substrate (20× magnification). The defects of standard IDE electrode fabrication are indicated by circles.

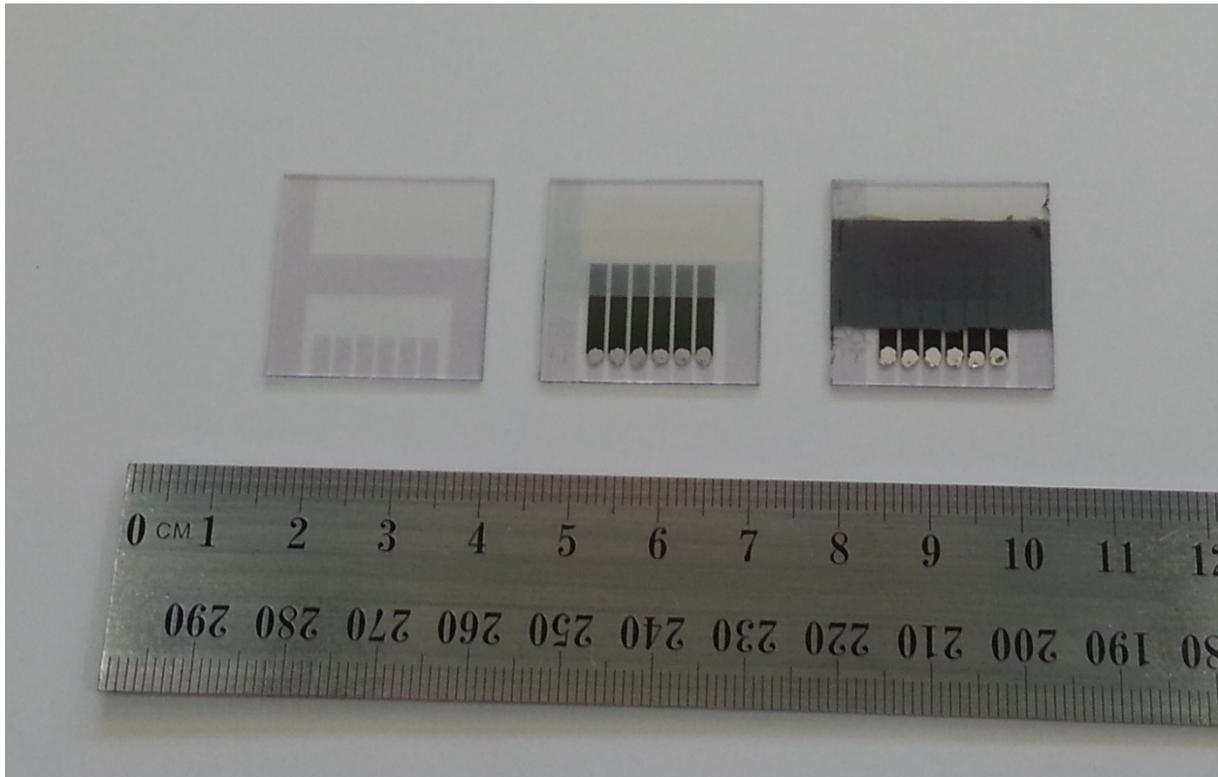


Fig. S2 Photographic image of a patterned ITO glass substrate with ~50 nm sputtered ZnO layer (left), QIDE (middle) and complete back-contacted perovskite solar cell device (right).

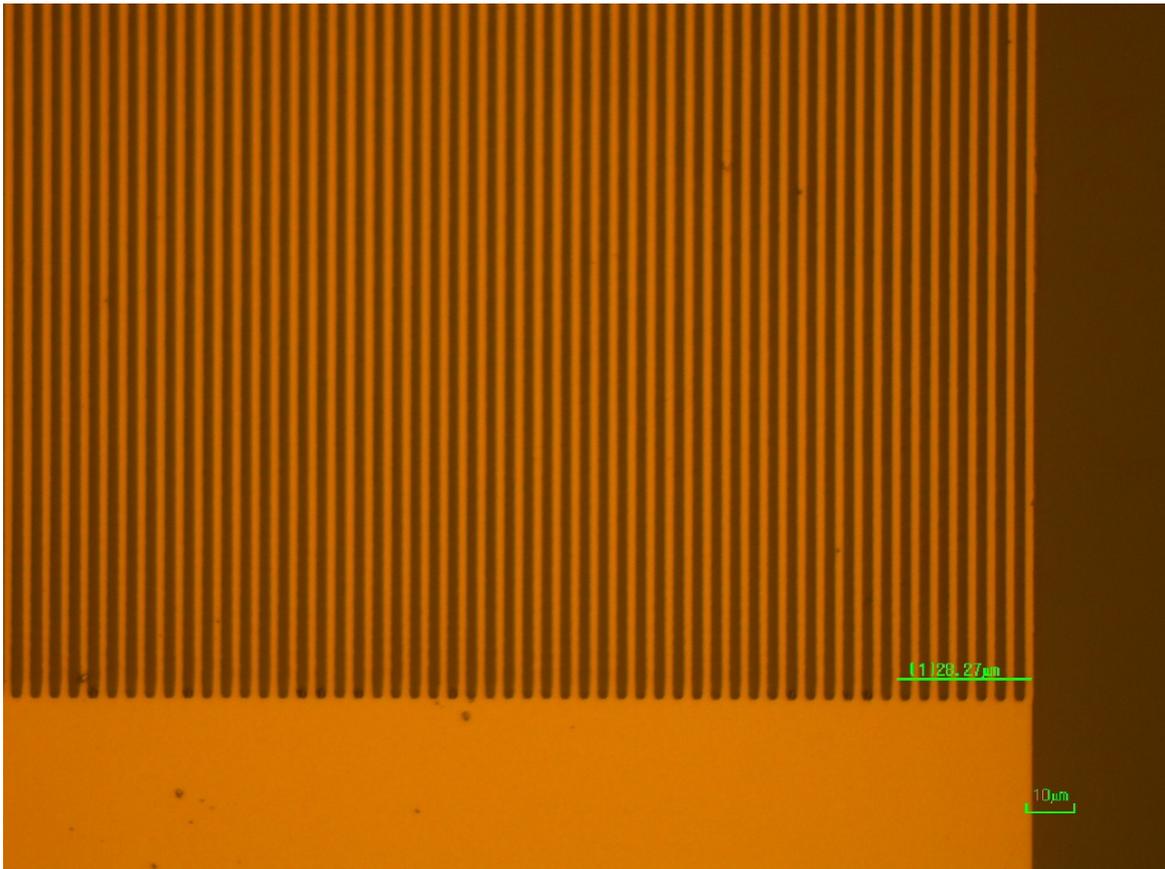


Fig. S3 Optical microscope image of QIDE on ITO glass substrate (50× magnification).

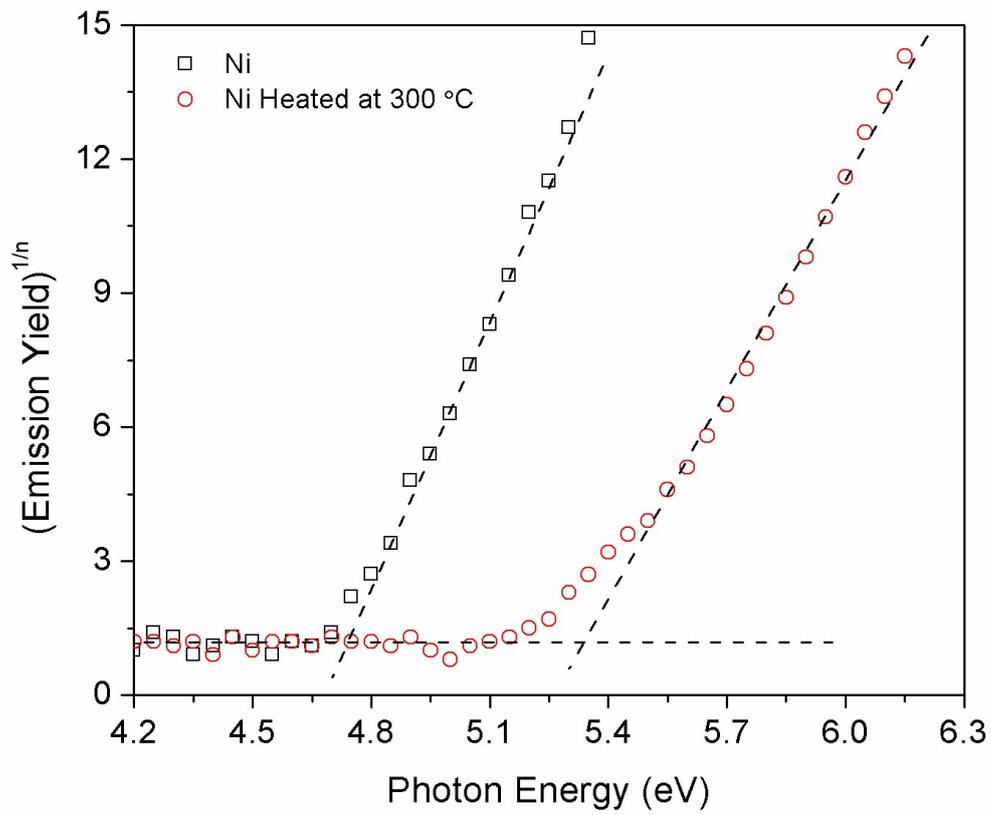


Fig. S4 PESA spectra of Ni and Ni heat-treated at 300 °C (NiO_x).

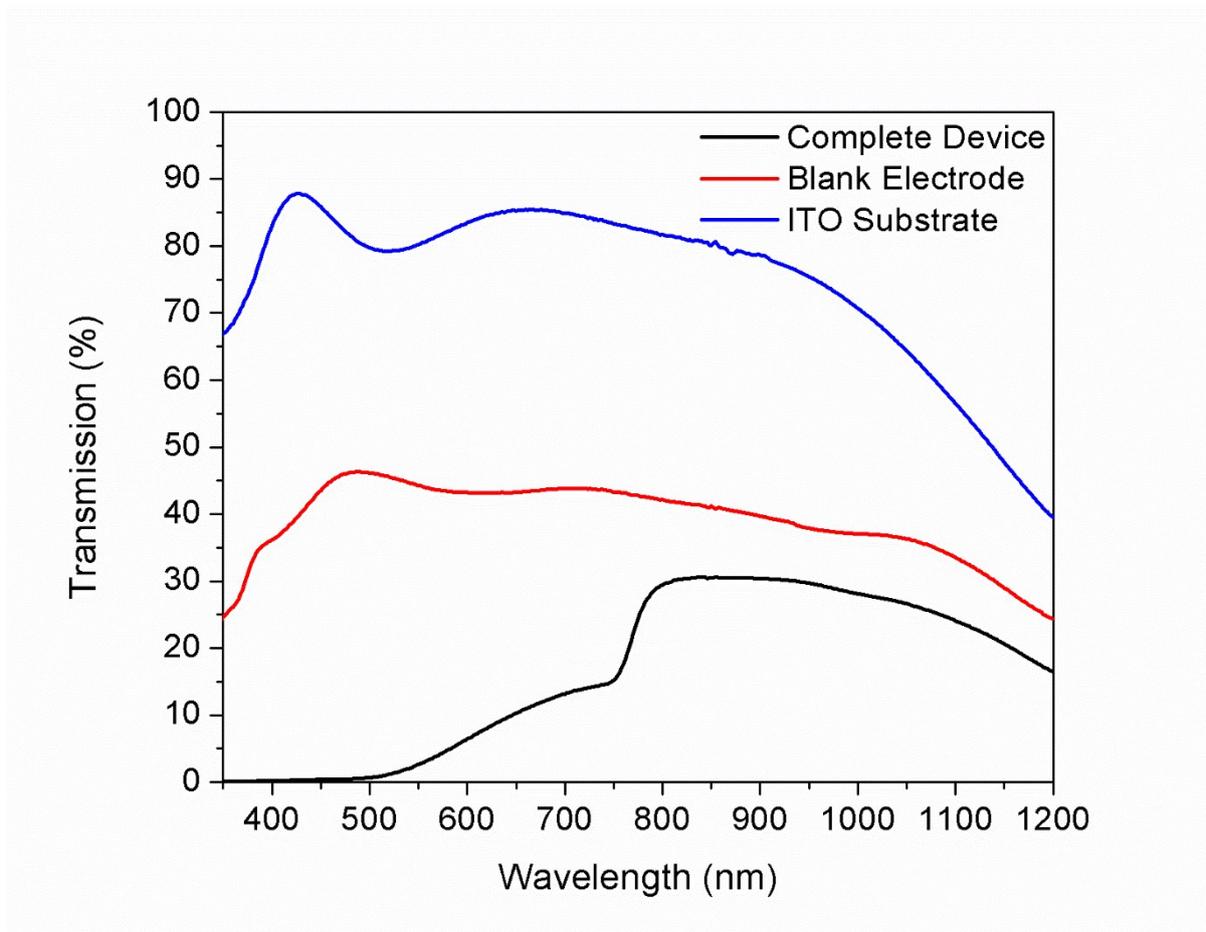


Fig. S5 Transmission of an ITO glass substrate, QIDE and complete back-contacted perovskite solar cell device.

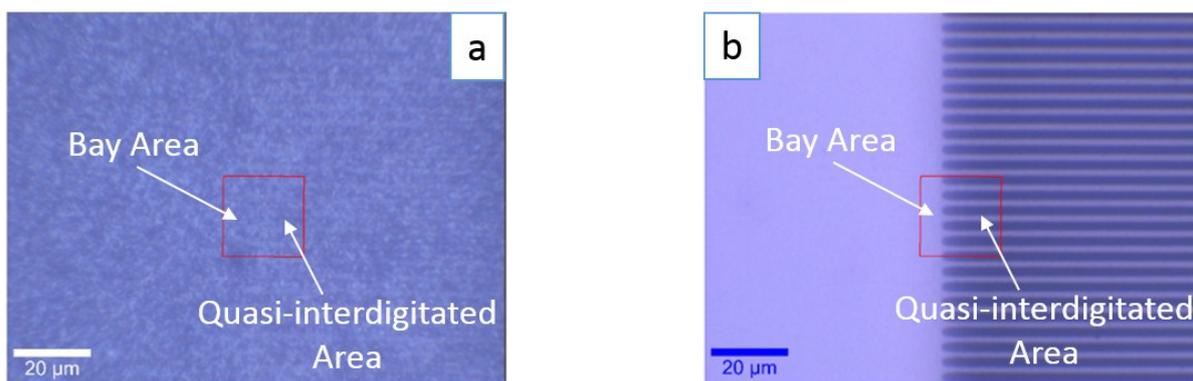


Fig. S6 Optical microscopy image of the back-contacted perovskite device; (a) Image from the absorber side (top) and (b) image from the ITO/glass side (bottom). The red square in the images is the scan area for the photoluminescence and photocurrent measurements.

References

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