Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C.

Supporting Information for

Quantum Efficiency Enhancement in Multi-Junction Solar Cells with Spectrally Selective and Conducting 1D Photonic Crystals

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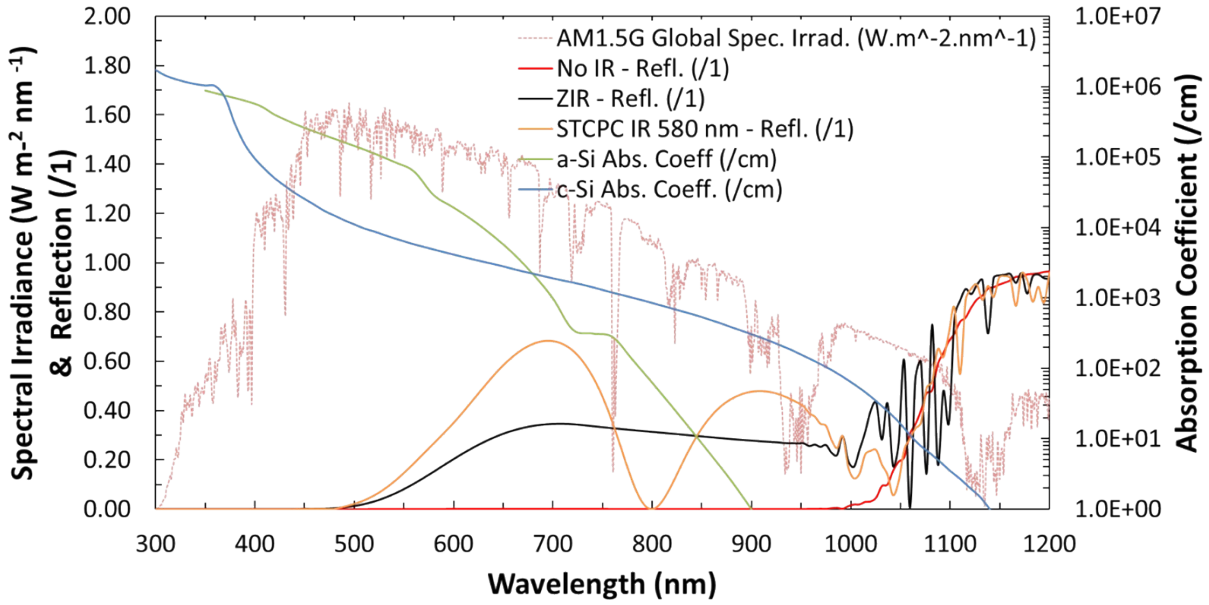

Fig. S1. AM 1.5G Global spectral irradiance, c-Si and intrinsic a-Si absorption coefficient curves (both plotted on a log scale), with overlaid internal reflectance spectra for tandem cells with IR configurations: no IR, ZIR, and STCPC IR (580 nm centre wavelength), as simulated by wave-optics analysis. The internal reflectance is simulated by assuming that light is incident from a thick slab of a-Si.. Thus, the internal reflectance curves provide information about the portion of light reflected from the a-Si/IR, or a-Si/c-Si interface and transmitted back to the upper surface of the thick a-Si slab (without being absorbed in this slab). The internal reflectance curve for the no IR configuration is zero up to 1 µm because the reflectance is negligible at the a-Si/IR interface, while this reflectance curve increases to non-zero values at wavelengths greater than 1 µm because light in this spectral region traverses through the entire structure and is reflected from the very bottom surface of the multi-junction cell. The internal reflectance curve for the ZIR configuration increases from 0 at ~500 nm to almost 40% at 700 nm; more light is reflected in the spectral vicinity near 700 nm because the a-Si absorption coefficient is relatively small, whereas any light reflected at 500 nm is absorbed in the thick a-Si slab before propagating to its upper surface. The internal reflectance curve for the STCPC IR configuration is greater than that for the ZIR configuration in the spectral region at the a-Si band-edge, between 500 nm and 750 nm, on account of the greater reflection from the STCPC compared to that of the ZIR. Further, it is interesting to note that while the STCPC has a Bragg-reflection peak at 580 nm, the internal

reflection curve for the STCPC IR configuration peaks at a wavelength closer to 700 nm. This is because a significant portion of the light reflected in the spectral vicinity of the Bragg-reflection peak at 580nm is absorbed in the thick a-Si slab before it reaches its upper surface.

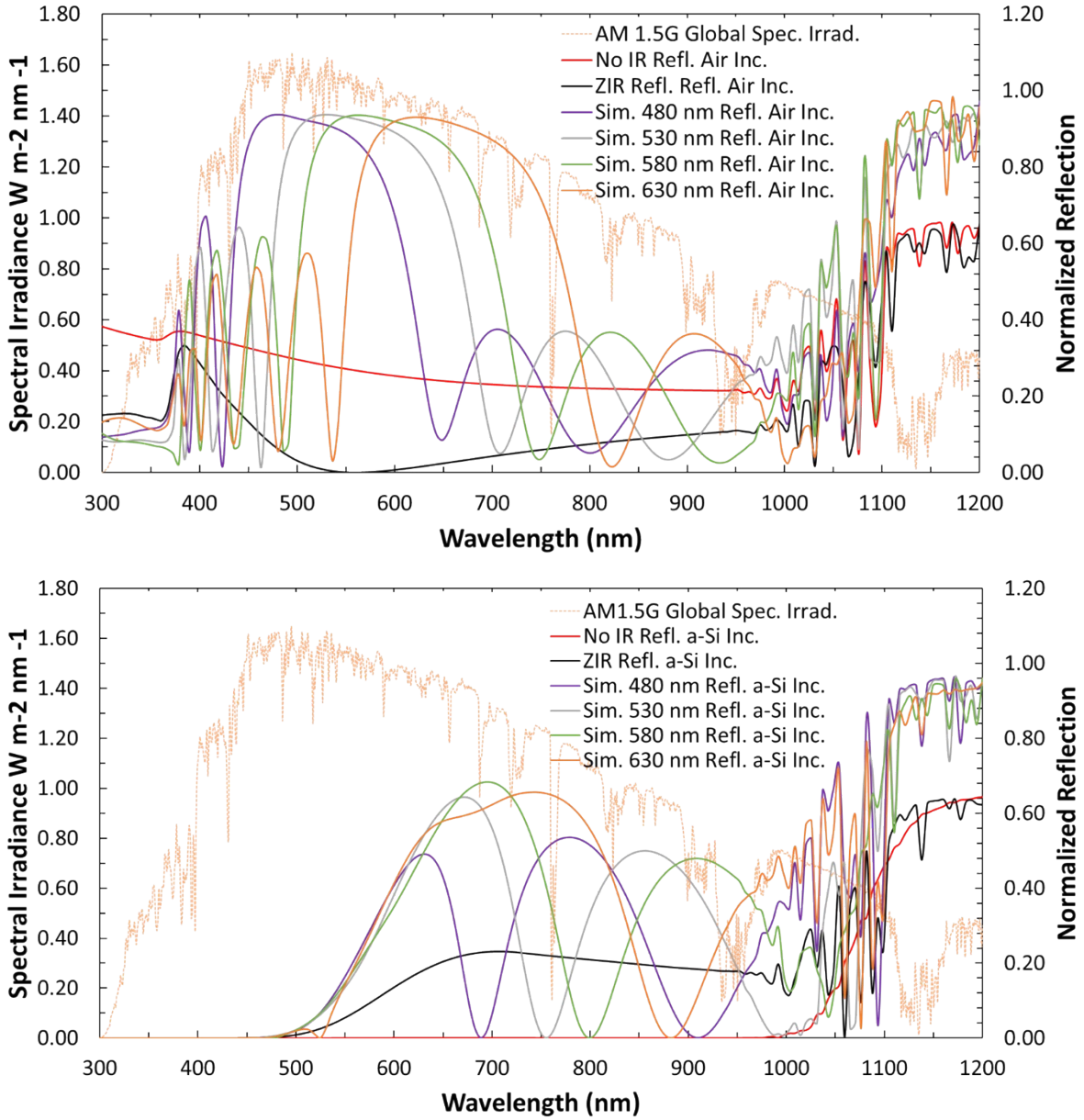

Fig. S2. AM 1.5 spectra, with overlaid reflectance spectra for various IR configurations, including no IR, ZIR, and STCPC IRs with various centre wavelength peak positions, all simulated by wave-optics simulation software. The reflectance spectra in the top plot are shown for light incident onto the surface of the IR from air. The bottom plot shows the internal reflectance spectra simulated by assuming that light is incident from a thick a-Si slab.

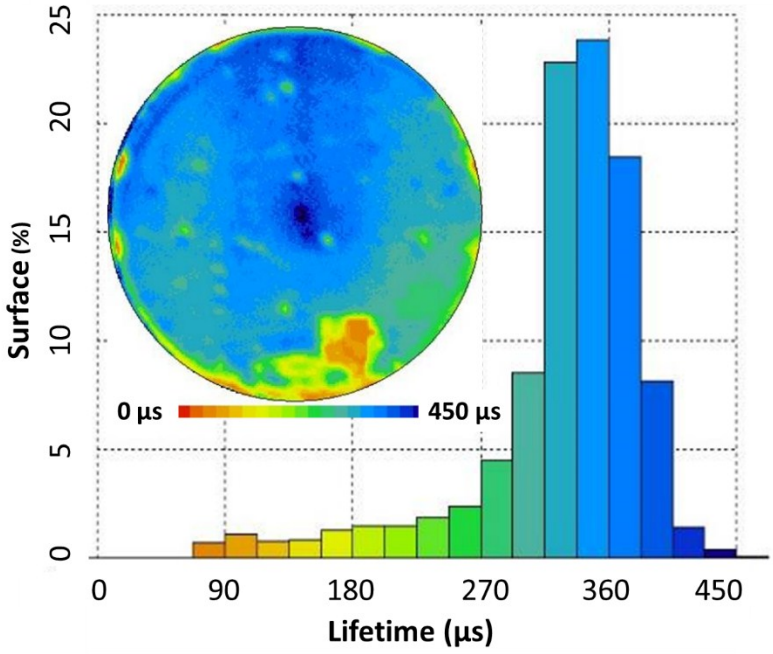

Fig. S3. Carrier lifetime distribution measured using µPCD for the bottom c-Si heterojunction cell used as the platform in the a-Si:H/c-Si heterojunction tandem cell structure. The lifetime distribution of the fabricated bottom c-Si heterojunction cell is mapped across the wafer surface, which is shown in the inset. The lifetime distribution peaks around 330 µs for the core part of the cell. Lowest lifetime cells (around 20 µs) experience about a 20-25% decrease in J_{SC} and resulting 1-2% drop in efficiency compared with 300 µs cells. However, these cells still do not place the tandem cell in a bottom limited current density configuration.

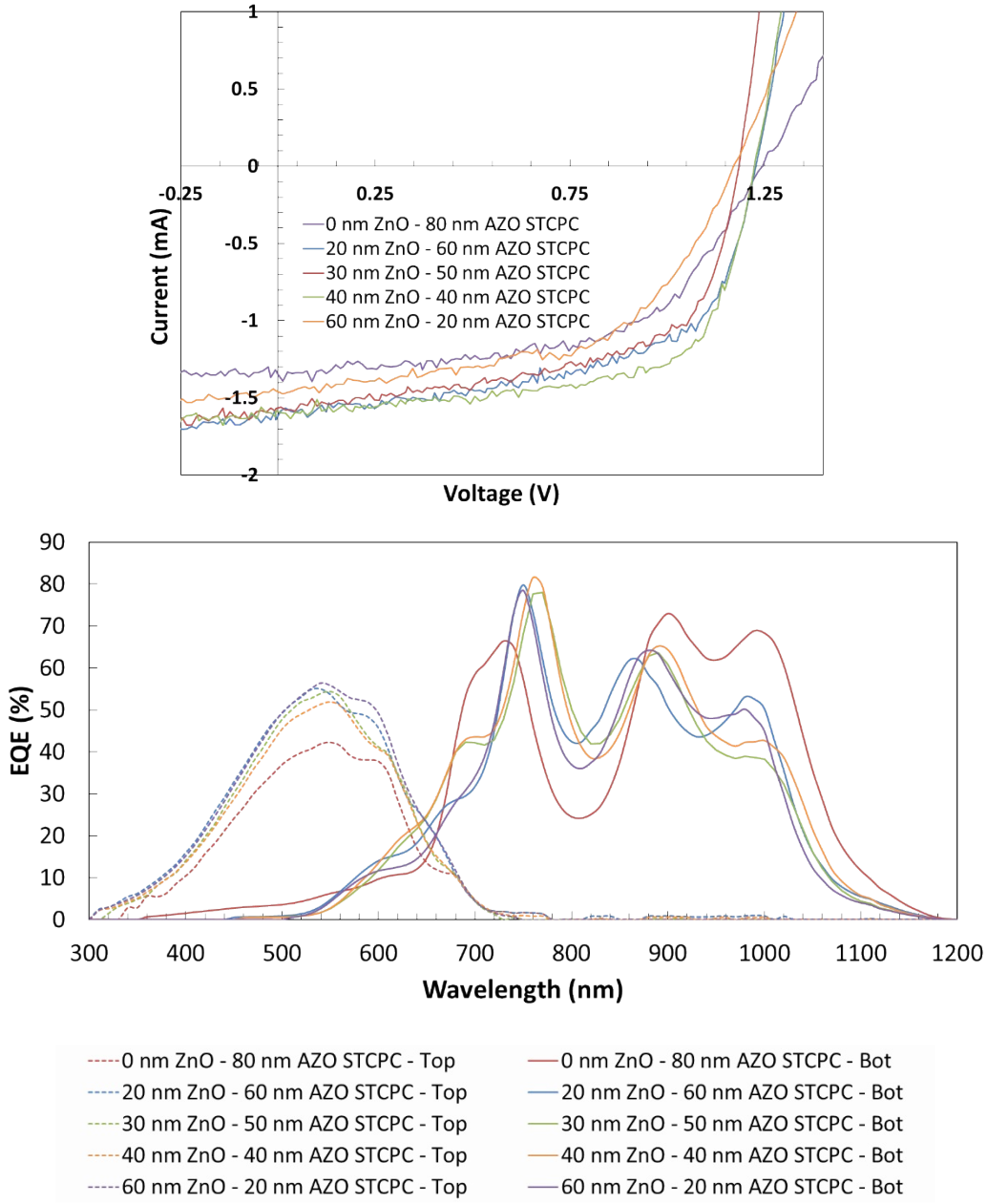

Fig. S4. The I-V curves (Top) and EQE results (Bottom) for a series of a-Si:H/c-Si HJ tandem cells with STCPC IR having a centre peak position of 580 nm. In this series, the relative thicknesses of the ZnO and AZO layers are varied within the ZnO/AZO hybrid layer, which is the uppermost TCO layer in the STCPC and is in contact with the a-Si:H cell. The ZnO thickness, t_{ZnO}, is increased from 0 to 60 nm in increments of 20 nm, while the total thickness of the ZnO/AZO hybrid layer is maintained at 80 nm. The t_{ZnO} / t_{AZO} = 0 nm/80 nm case had the lowest cell yield from the low lateral resistivity causing shunting through the top a-Si:H cell component. The 20 nm/60 nm, 30 nm/50 nm, and 40 nm/40 nm cases show a good balance between low and series resistance, and high cell yield with the 40-40 case showing the best performance. The electrical cell performance parameters are listed in Table S1.

Table S1. Electrical/Solar Simulator Cell Performance Parameters from Optimization of the top ZnO/AZO Hybrid Layer in the STCPC IR with centre peak position at 580 nm (top cells by FF**, functional cells designated by FF > 50%)

Case (ZnO Thickness [nm] – AZO Thickness [nm])	J_{SC} [mA/cm^2]	Η [%]	I_{SC} [mA]	V_{OC} [V]	FF [%]	Functional Cell Count
0-80	5.45	3.95	1.33	1.24	58.65	1
20-60	6.72	4.52	1.65	1.22	55.32	10
30-50	6.70	4.11	1.64	1.16	53.08	15
40-40	6.84	4.53	1.68	1.20	55.57	20
60-20	6.18	3.88	1.18	1.18	53.09	4

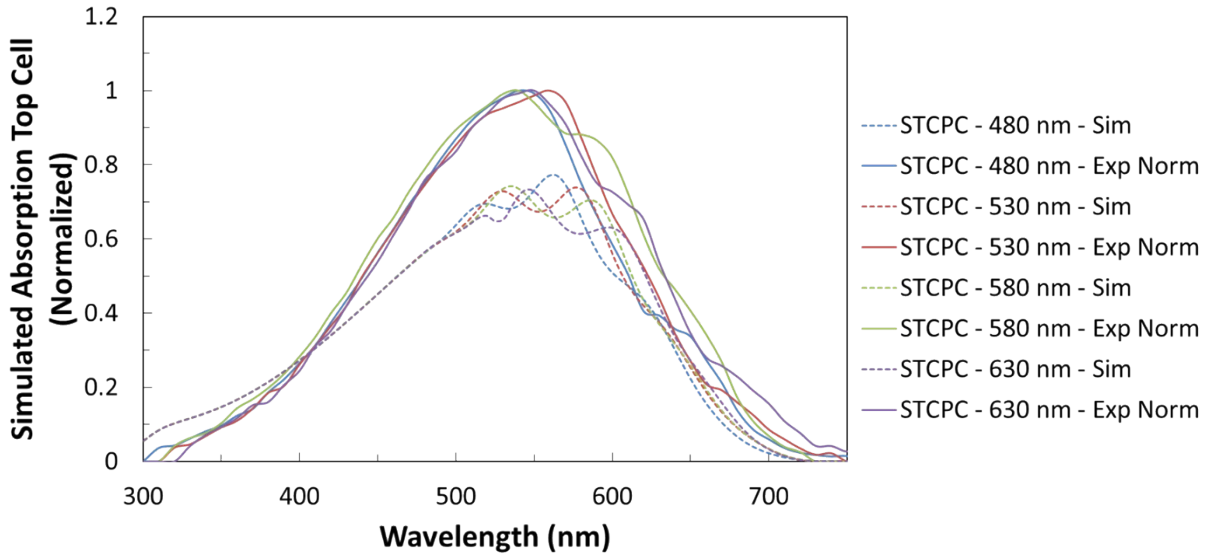

Fig. S5. Simulated (dashed) absorption in the top cell within the tandem cells with STCPC IRs having centre wavelengths of 480, 530, 580 and 630 nm. Experimental (solid) curves (normalized to 1) are overlaid to compare curve shapes.

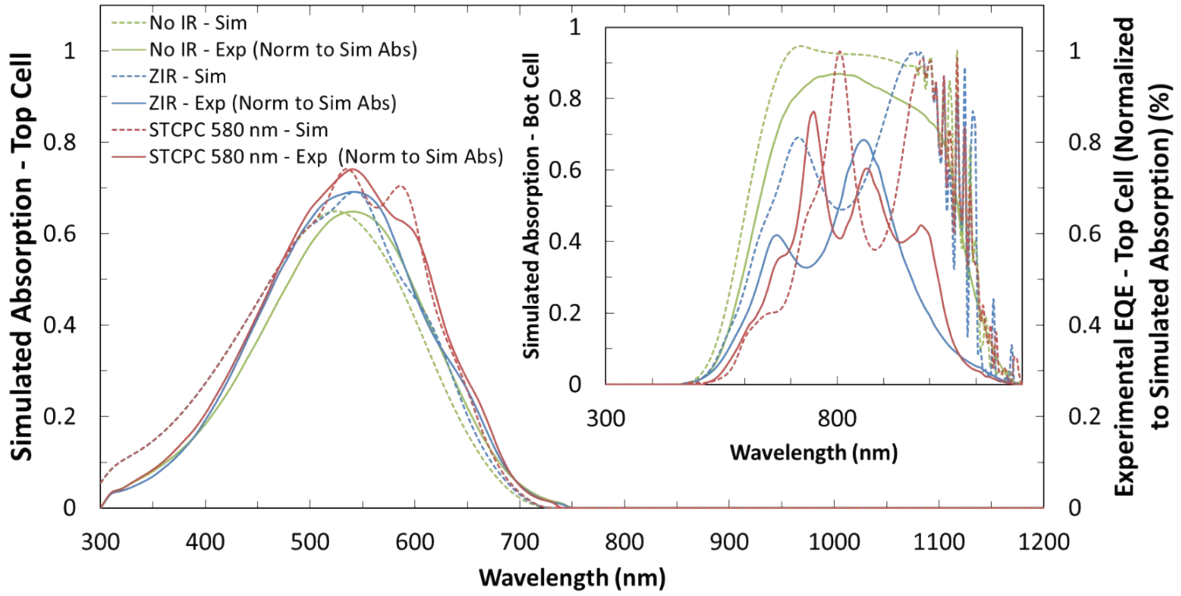

Fig. S6. Simulated (dashed) absorption curves for the top a-Si:H cells in the 3 cases of no IR, ZIR, and STCPC IR. Overlaid are experimental (solid) EQE curves, normalized to the simulated absorption peak height for clarity of presentation. The inset graphic provides the simulated curves for the corresponding bottom cell, and original (not normalized) EQE curves for the bottom c-Si HJ cell.