Supplementary File

Dielectric Shells as Resonant Mode Tuners: Unlocking Superior Visible-Spectrum Photon Capture in Plasmonic Perovskite Solar Cells

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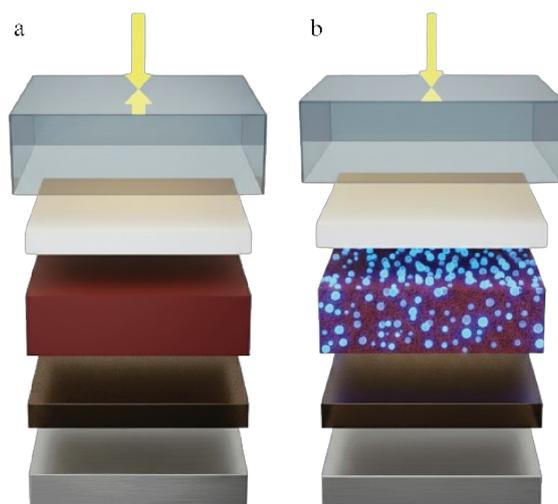**Corresponding:** tariqul@ukm.edu.my, shabiul.islam@mmu.edu.my, mohamed.ouda@udst.edu.qa.

Fig. S1: Planar and photonic crystal-embedded perovskite solar cell structure
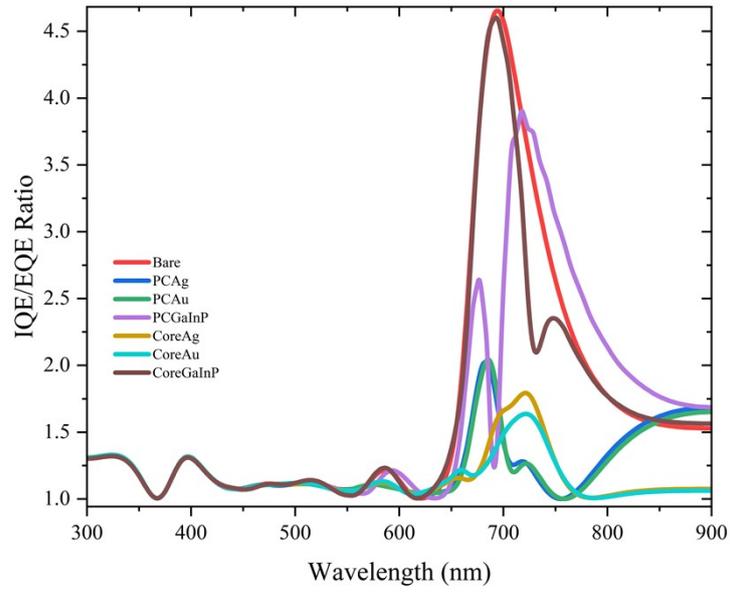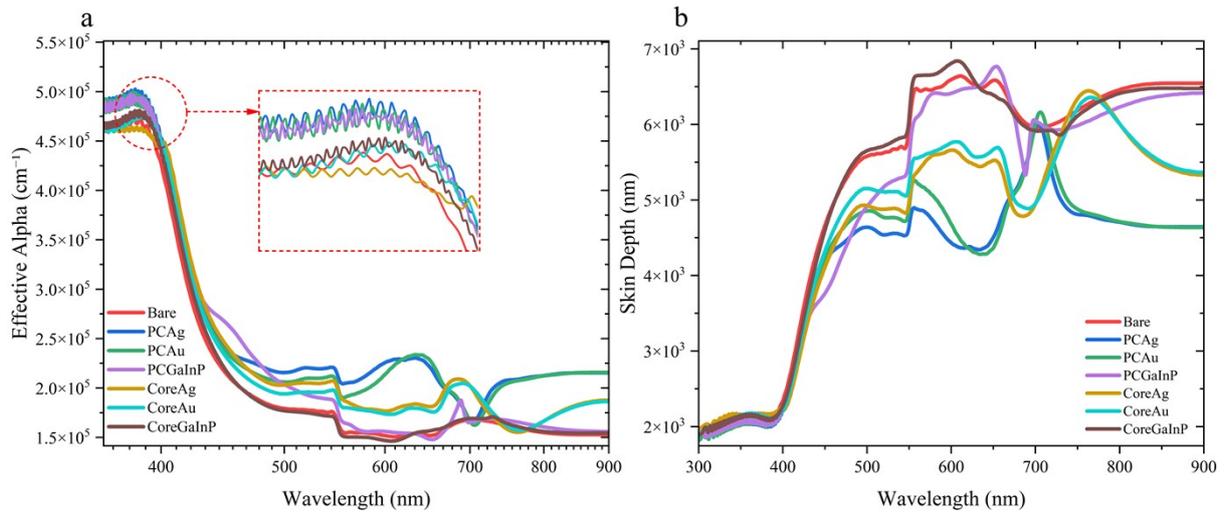
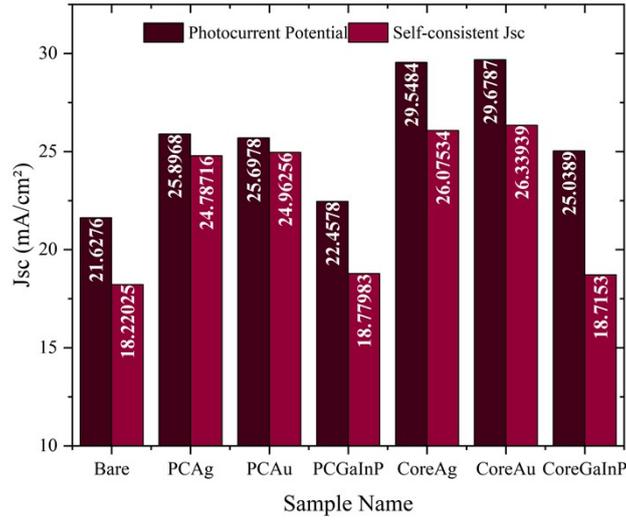**Fig. S2: IQE/EQE Ratio**

Fig. S3: Effective Alpha and Skin Depth

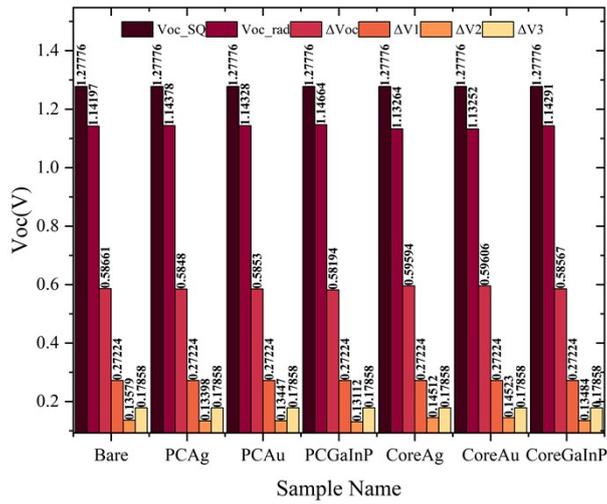**Fig. S4: Photocurrent Potential versus Self-Consistent Jsc**
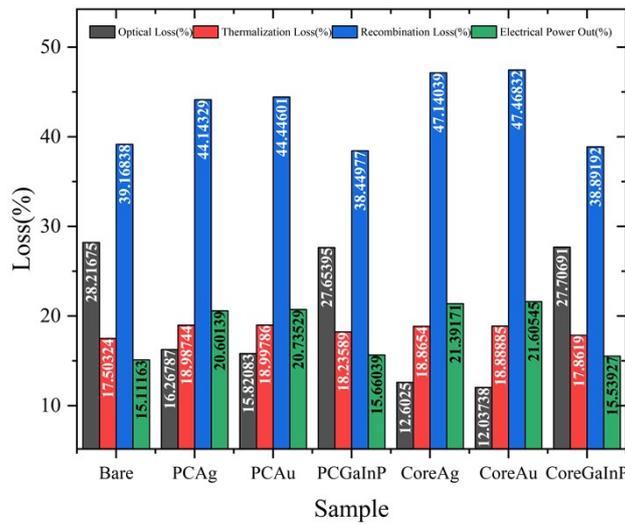

Fig. S5: Voc Loss Analysis

Fig. S6: Power Loss Waterfall Analysis

Table S1: Layer stack and material properties for the FDTD optical simulation

Layer Name	Role	Material Model	Thickness (nm)
FTO	Transparent Front Contact	FTO - Hamed Saghaei[12]	200 nm
TiO2	Electron Transport Layer	TiO_2 - Sarkar[13]	42 nm
MAPbI3	Absorber Layer	$MAPbI_3$ - Phillips[14]	350 nm
Spiro-OMeTAD	Hole Transport Layer	Spiro-OMeTAD	180 nm
Au	Back Contact / Reflector	Au (Gold) – Palik[15]	60 nm

Table S2: Optimized Photonic Crystal Parameters

PhC Configuration	Shell Thickness (nm)	Core Radius (nm)	Periodicity (nm)	Y-offset
PCAg, PCAu, PCGaInP	0	100	360	Centered at $MAPbI_3$/Spiro-OMeTAD interface
CoreAg, CoreAu, CoreGaInP	17	100	380	Centered at $MAPbI_3$/Spiro-OMeTAD interface

Table S3: Key Electrical Simulation Parameters

Parameter	Value
Absolute Temperature (K)	300
Perovskite Bandgap Energy (eV)	1.55
Perovskite Layer Thickness (nm)	350
Diode Ideality Factor (n)	1.2
Richardson's Constant ($A\ cm^{-2}\ K^{-2}$)	120
External Luminescence EQE (EQE_{EL})	0.001
Series Resistance ($\Omega \cdot cm^2$)	0.5
Shunt Resistance ($\Omega \cdot cm^2$)	1000

S1. Methodology for Strategic Photocurrent Gain Analysis

To quantify the photocurrent budget of each nanophotonic design relative to the Bare cell baseline, in Table S4, the following analysis was performed.

The spectral difference in reflectance, $\Delta R(\lambda)$, was calculated across the entire wavelength range:

$$\Delta R(\lambda) = RBare(\lambda) - RSample(\lambda)$$

A positive $\Delta R(\lambda)$ indicates a region where the sample device is less reflective than the baseline, while a negative value indicates a region where it is more reflective. This reflectance difference was then converted into a spectral photocurrent density difference, $\Delta J(\lambda)$, by weighting it with the standard AM1.5G solar photon flux, $\Phi_{AM1.5G}(\lambda)$:

$$\Delta J(\lambda) = q \cdot \Delta R(\lambda) \cdot \Phi AM1.5G(\lambda)$$

where q is the elementary charge.

Finally, the total gain (J_{gain}) and loss (J_{loss}) were calculated by integrating the positive and negative components of $\Delta J(\lambda)$ separately over the entire spectrum:

$$Jgain = \int \Delta J(\lambda) > 0 \Delta J(\lambda) d\lambda$$

$$Jloss = \int \Delta J(\lambda) < 0 \Delta J(\lambda) d\lambda$$

The net gain (J_{net}) is the sum of these two components. This method allows for a complete and quantitative deconstruction of the performance trade-offs associated with reflection management.

Table S4: Strategic Photocurrent Gain Analysis

Sample Name	J_{gain}(mA/cm²)	J_{loss}(mA/cm²)	J_{net}(mA/cm²)
PCAg	4.92	-0.26	4.66
PCAu	5.07	-0.22	4.85
CoreAg	0.39	-0.18	0.21
CoreAu	6.55	-0.1	6.45
CoreGaInP	6.79	-0.11	6.68
PCGaInP	1.05	-1	0.05