# Interface modification of hole transport layer in tin-based halide perovskite solar cells

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**Note S1**. The current density-voltage characteristics of PEDOT:PSS film as an active layer (ITO/SAM/PDEOT:PSS/Cu).

The HTL layer is approximately 40 nm thick and has an effective area of 0.05 $cm^2$. The control, MeO-2PACz, and Me-4PACz exhibited conductivities of 0.06967 S, 0.10784 S, and 0.12939 S, respectively. The calculated values were $0.55736 \times 10^{-2}$ mS $cm^{-1}$, $0.86272 \times 10^{-2}$ mS $cm^{-1}$, and $1.03512 \times 10^{-2}$ mS $cm^{-1}$, respectively, using the equation.

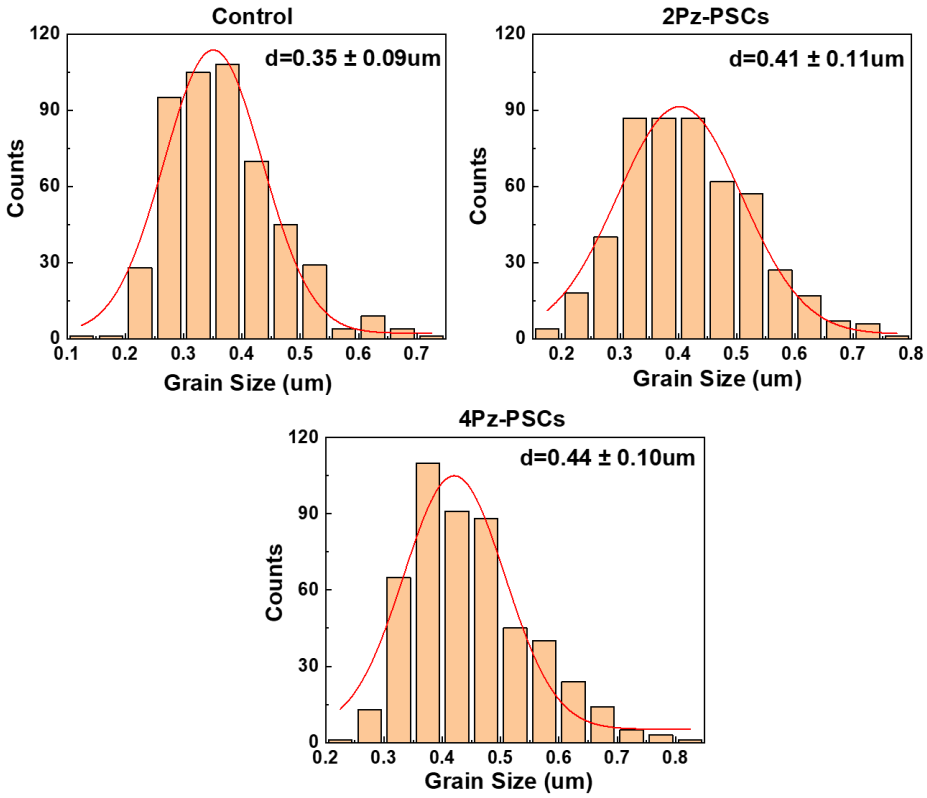


**Figure S1**. Size distribution histogram determined from top-view SEM image.

**Table S1**. The information of Sn XPS measurement deconvoluted into $Sn^{2+}$ and $Sn^{4+}$ peaks for control, 2Pz and 4Pz perovskite thin layers.

| Sample | Ionic | Peak index | BE (ev) | FWHM (ev) | Percentage (%) | Relative ratio ($Sn^{4+}/Sn^{2+}$) [%] |
|---|---|---|---|---|---|---|
| Control | $Sn^{2+}$ | Sn $3d_{5/2}$ | 486.00 | 1.17 | 32.66 | 45.0 |
| | | Sn $3d_{3/2}$ | 494.41 | 1.17 | 32.87 | |
| | $Sn^{4+}$ | Sn $3d_{5/2}$ | 486.77 | 1.16 | 17.22 | |
| | | Sn $3d_{3/2}$ | 495.19 | 1.16 | 17.25 | |
| 2Pz/PVSK | $Sn^{2+}$ | Sn $3d_{5/2}$ | 486.06 | 1.18 | 34.59 | 44.1 |
| | | Sn $3d_{3/2}$ | 494.48 | 1.18 | 34.82 | |
| | $Sn^{4+}$ | Sn $3d_{5/2}$ | 486.81 | 0.98 | 15.25 | |
| | | Sn $3d_{3/2}$ | 495.22 | 0.98 | 15.34 | |
| 4Pz/PVSK | $Sn^{2+}$ | Sn $3d_{5/2}$ | 486.07 | 1.19 | 37.70 | 32.2 |
| | | Sn $3d_{3/2}$ | 494.48 | 1.19 | 37.92 | |
| | $Sn^{4+}$ | Sn $3d_{5/2}$ | 486.84 | 0.98 | 12.15 | |
| | | Sn $3d_{3/2}$ | 495.26 | 0.98 | 12.23 | |

**Table S2**. Fitted PL lifetimes of control and SAM-modified Sn-based perovskite films on glass substrates. $A_1$ and $A_2$ are fractional intensities, and $\tau_1$ and $\tau_2$ are lifetimes. The average carrier lifetime ($\tau_{ave}$) was calculated with $\tau_{ave} = A_1*\tau_1+A_2*\tau_2$.

| | $A_1(\%)$ | $\tau_1\ (ns)$ | $A_2(\%)$ | $\tau_2\ (ns)$ | $\tau_{ave}\ (ns)$ |
|---|---|---|---|---|---|
| Control | 1.52 | 0.50 | 0.06 | 3.94 | 1.0 |
| 2Pz/PVSK | 0.99 | 1.65 | 0.07 | 4.78 | 2.0 |
| 4Pz/PVSK | 1.05 | 1.67 | 0.02 | 16.46 | 2.1 |

**Figure S2**. Champion device optical current density-voltage forward and reverse sweep curves.

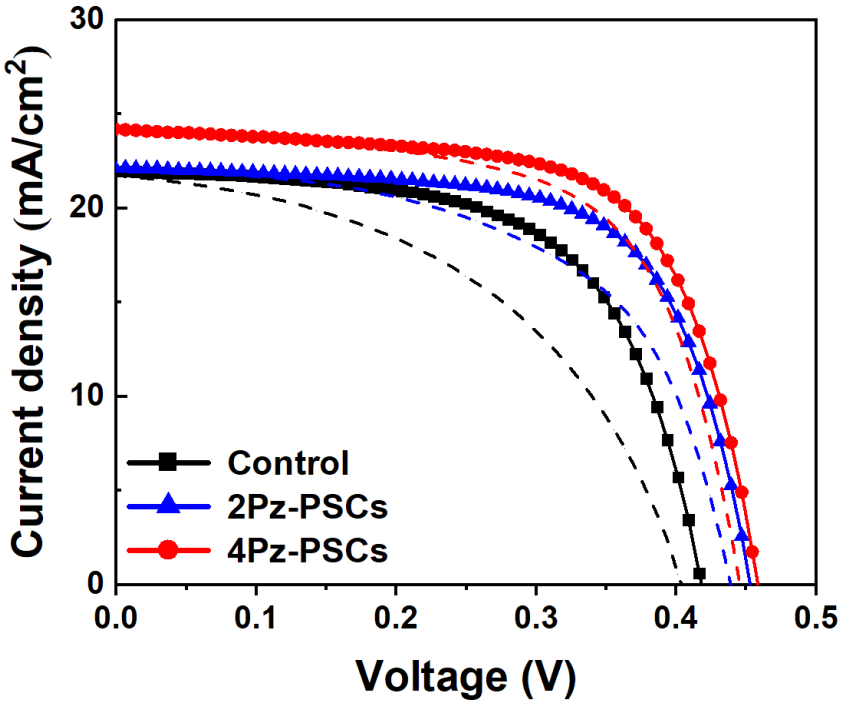

**Table S3**. Data were obtained from the EIS fitting circuit.

$$\tau = RC$$

| Sample | $R_{rec}$ (Ω) | C (F) | $\tau$ (μs) |
|---|---|---|---|
| Control | 11747 | $7.238E^{-9}$ | 85.018 |
| 2Pz-PSCs | 16975 | $6.612E^{-9}$ | 112.243 |
| 4Pz-PSCs | 18483 | $7.292E^{-9}$ | 134.778 |

**Figure S3**. DLTS spectra of (a) control devices, (b) 2Pz-PSCs, and (c) 4Pz-PSCs.