# Supplementary Information

## Performance and Stability Enhancement of Perovskite Photodetectors by Additive and Interface Engineering Using a Dual-Functional PPS Zwitterion

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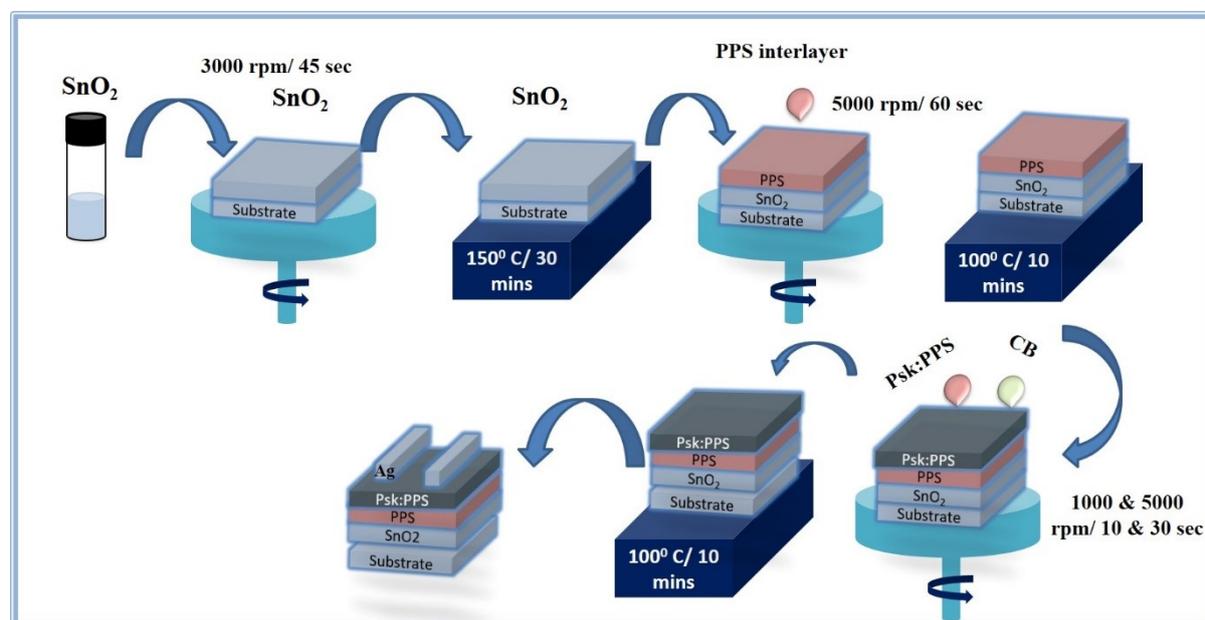
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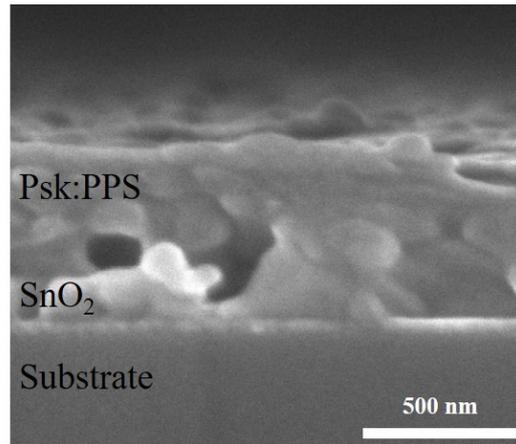**Fig. S1:** Detailed fabrication process

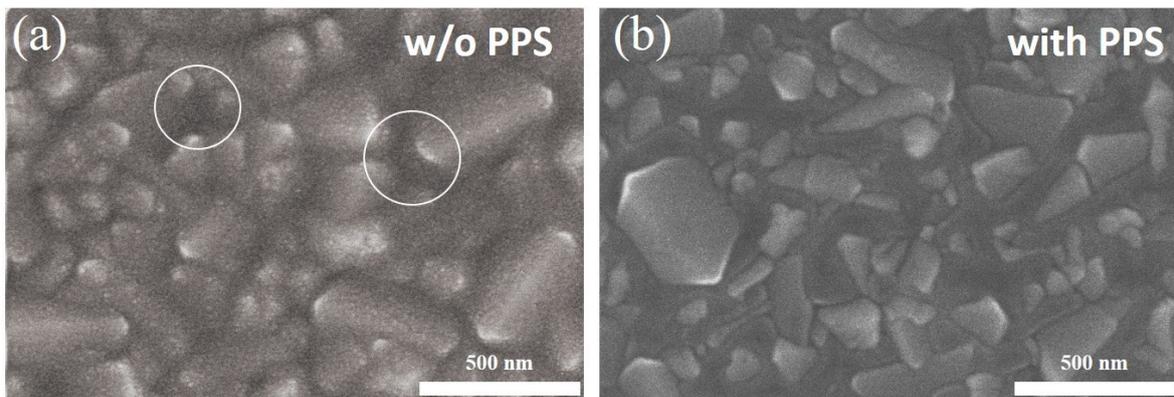**Fig. S2:** Cross-sectional SEM image of device without PPS inerlayer



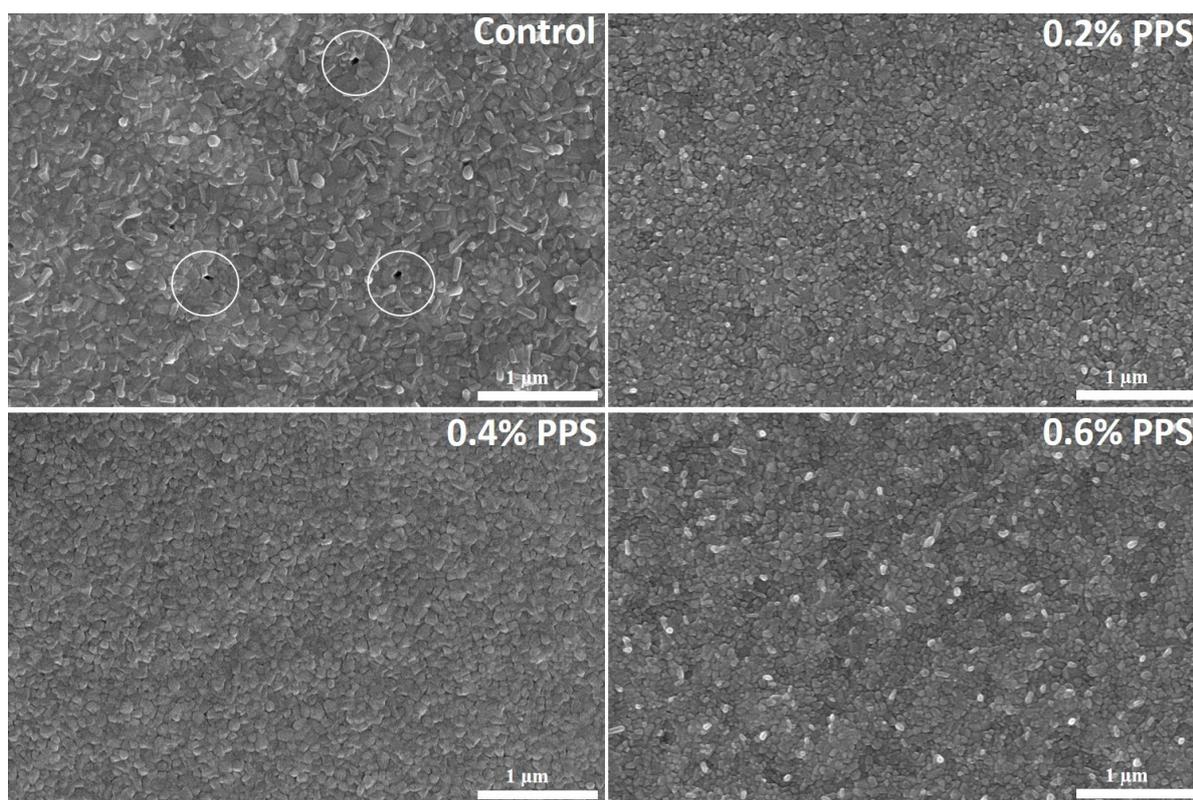**Fig. S3:** Top-view SEM images of $SnO_2$ (a) without PPS (b) with PPS

**Fig S4:** Large area too-view SEM images of perovskite films at (a) Control 0% (b) 0.2% PPS (c) 0.4% PPS (c) 0.4% PPS (d) 0.6% PPS
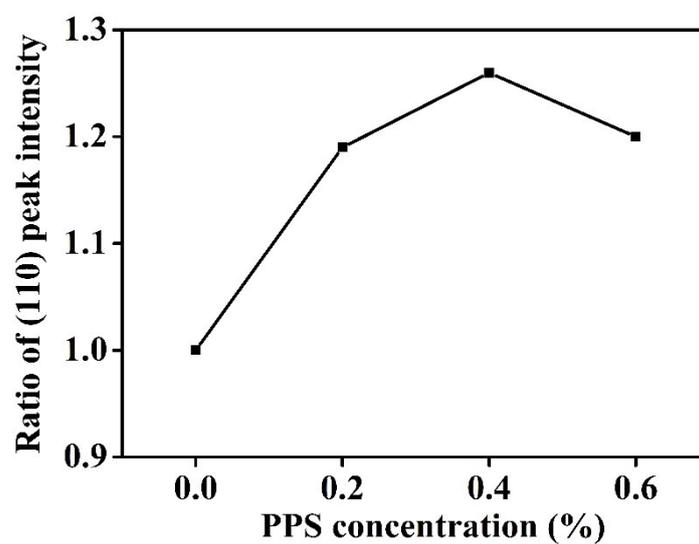


**Fig S5:** Ratio of (110) peak intensity of perovskite with various PPS concentration.
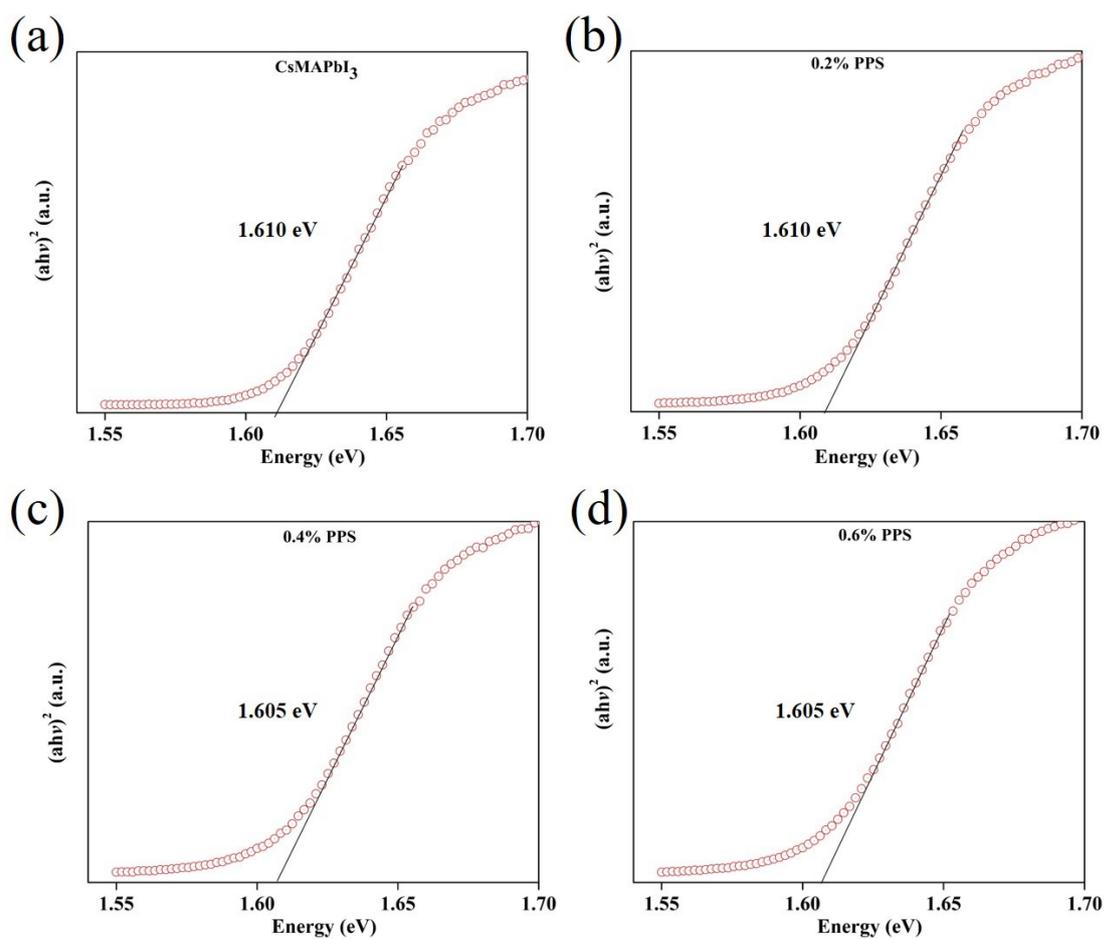
**Fig S6:** Tauc plot of (a) CsMAPbI$_3$ (b) 0.2% PPS (c) 0.4% PPS (d) 0.6% PPS
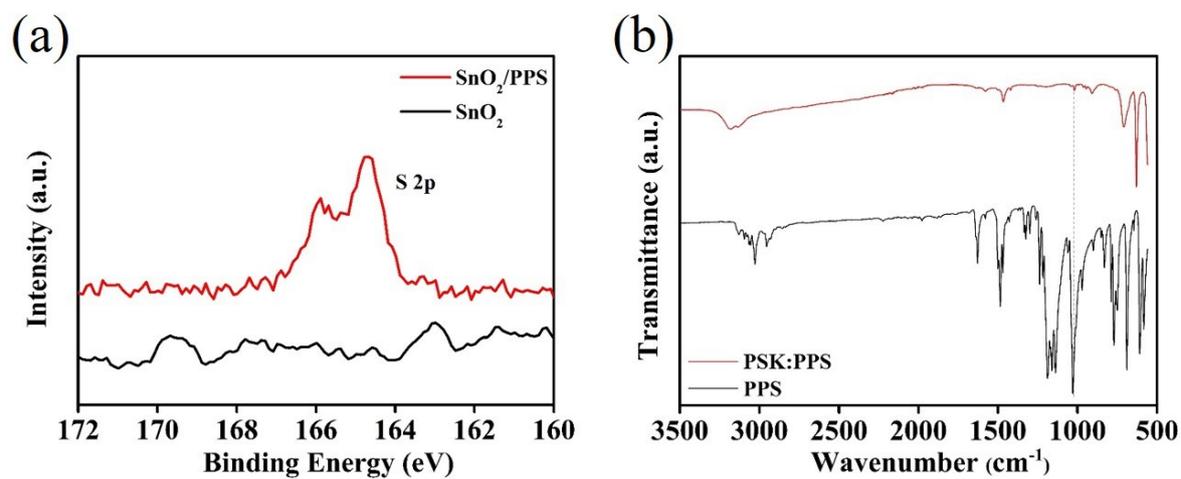


**Fig S7:** (a) XPS spectra of S 2p of SnO$_2$ and SnO$_2$/PPS layers. (b) FTIR spectra of PPS and PPS zwitterion incorporated perovskite.
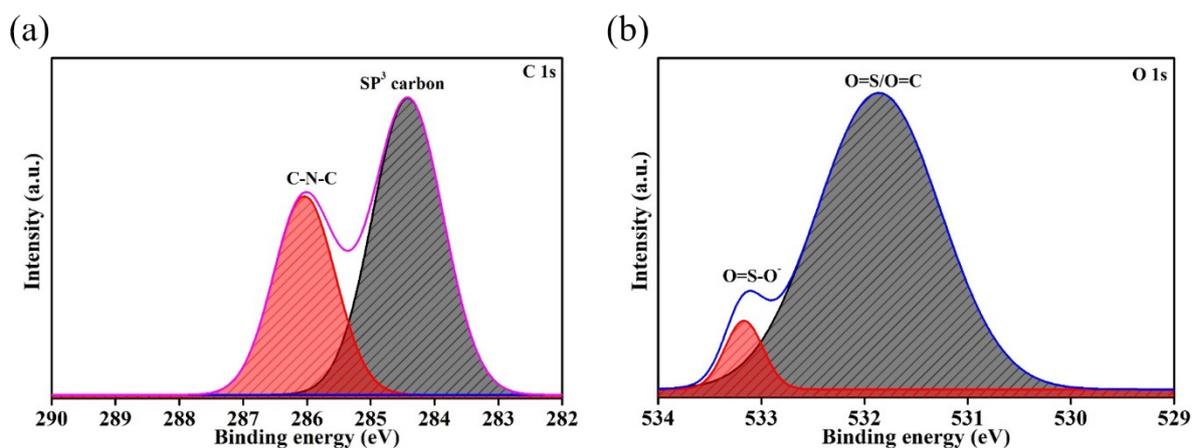
**Fig S8:** Deconvoluted C 1s and (d) deconvoluted O 1s spectra of Perovskite.
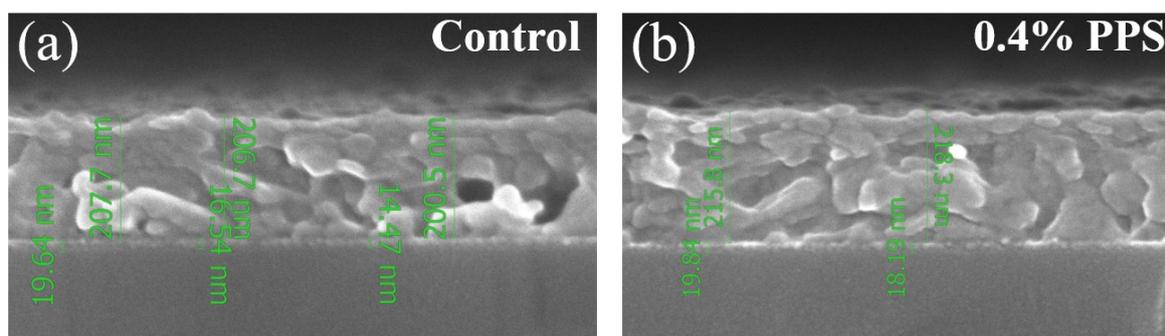


**Fig S9:** Cross-sectional SEM Images with the thickness (a) control and (b) 0.4% PPS incorporated perovskite films
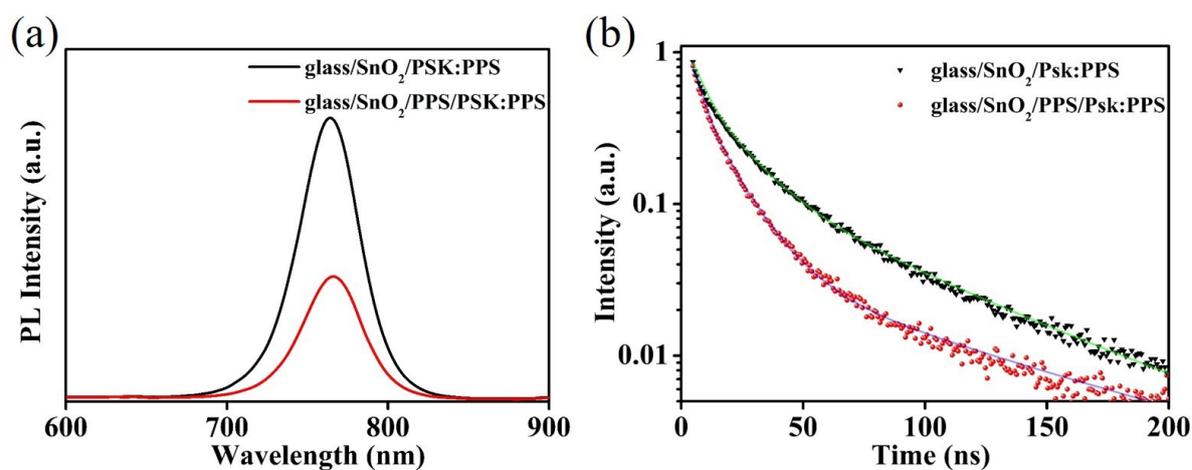


**Fig S10:** (a) PL spectra of complete devices (b) TRPL spectra of complete devices
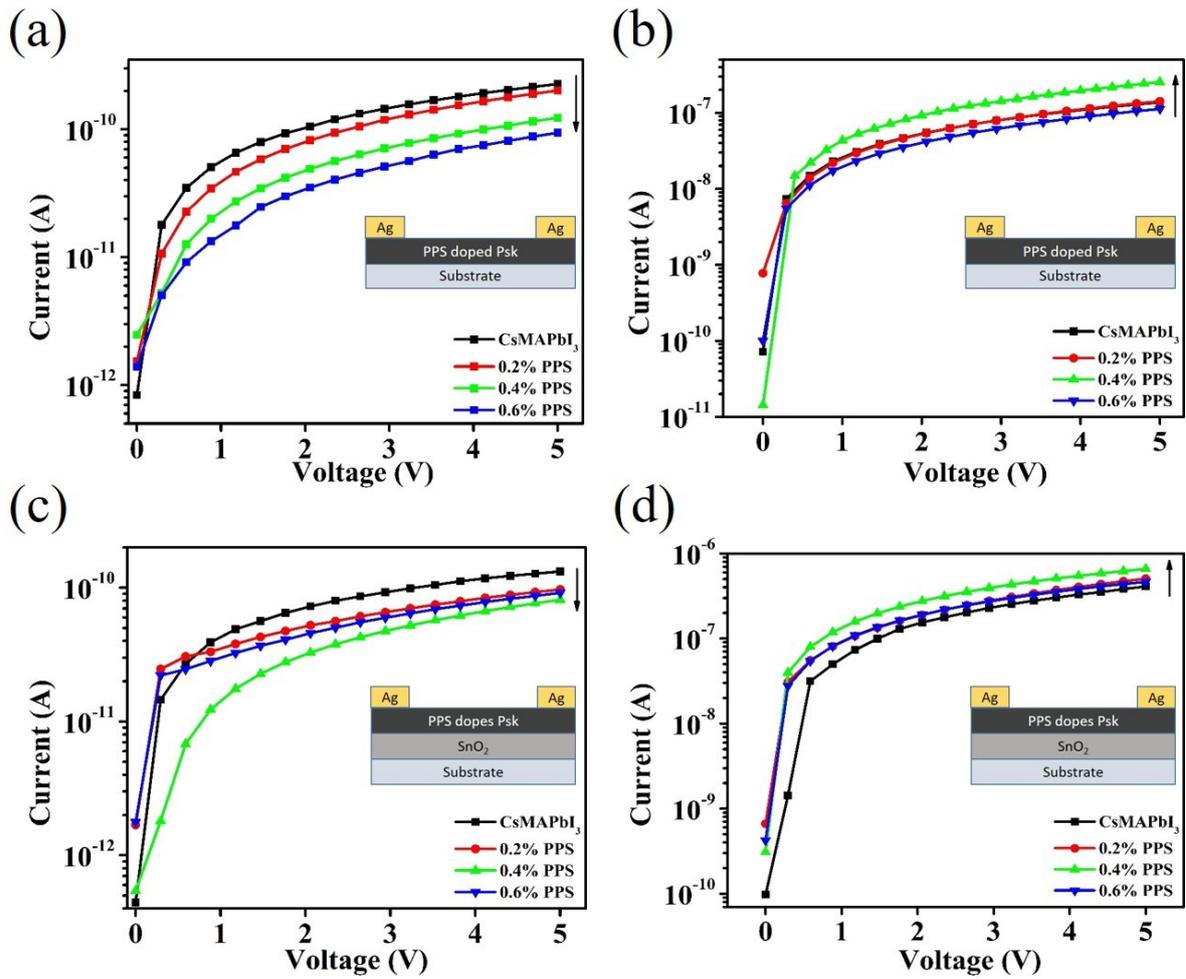
**Fig S11:** Perovskite only devices at different concentrations (a) dark current (b) photocurrent. PPS incorporated Perovskite devices with $SnO_2$ layer (c) dark current (d) photocurrent
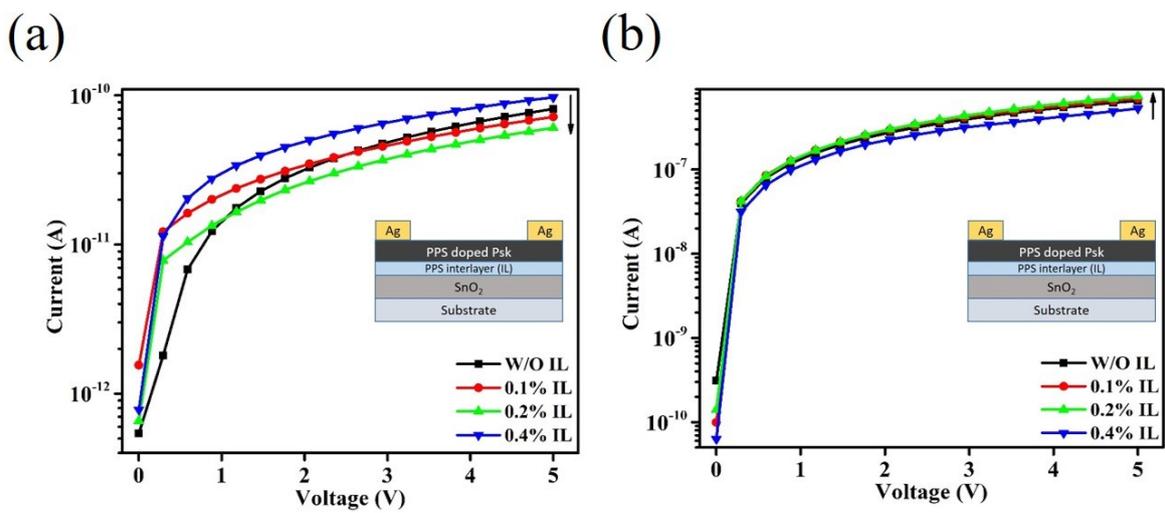


**Fig S12:** Different interlayer concentration of PPS (a) dark current (b) photocurrent

| W/O PPS - Fresh | With PPS - Fresh | W/O PPS – 10 Days | With PPS – 10 Days |
|---|---|---|---|



| W/O PPS – 20 Days | With PPS – 20 Days | W/O PPS – 30 Days | With PPS – 30 Days |
|---|---|---|---|
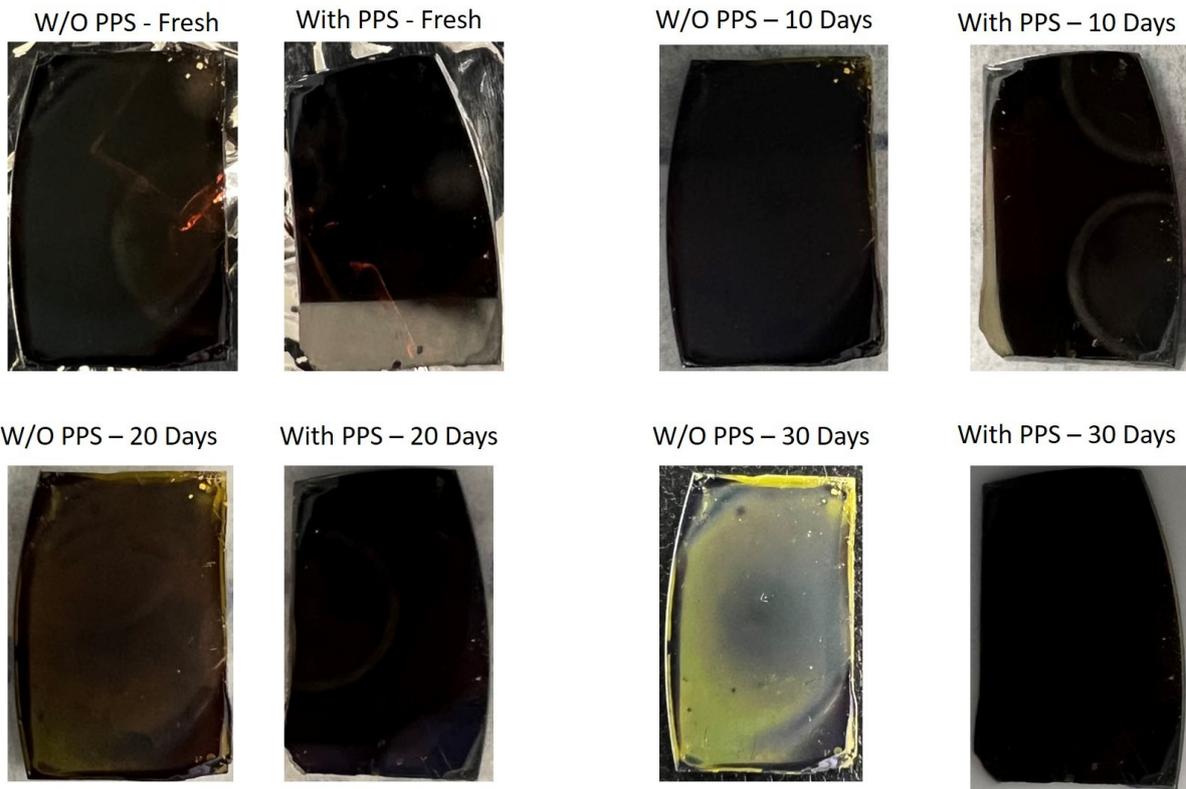
**Fig S13:** Sample stability images with and without PPS for over 30 days.

| W/O PPS - Fresh | With PPS - Fresh | W/O PPS – 4 hrs, T=130° C | With PPS – 4 hrs, T=130° C |
|---|---|---|---|



| W/O PPS – 8 hrs, T=130° C | With PPS – 8 hrs, T=130° C | W/O PPS – 24 hrs, T=130° C | With PPS – 24 hrs, T=130° C |
|---|---|---|---|
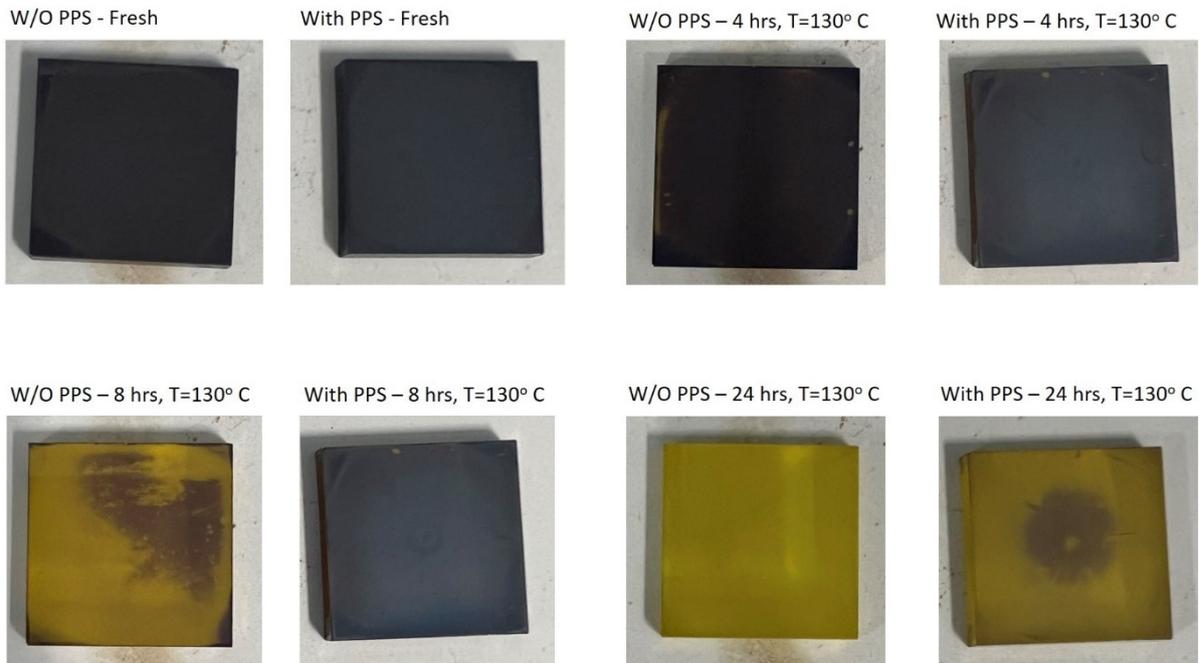
**Fig S14:** Thermal stability of samples with and without PPS

**Table S1:** FWHM and Crystallite size of (110) peak of perovskite with different concentration of PPS.

|  | FWHM | Crystallite Size (nm) |
|---|---|---|
| **Control** | 0.1359 | 65.5 |
| **0.2%** | 0.1374 | 64.80 |
| **0.4%** | 0.1385 | 64.28 |
| **0.6%** | 0.1404 | 63.32 |

**Table S2:** FWHM of control and with PPS incorporated perovskite films.

| Peak | FWHM of Control | FWHM of Psk:PPS (0.4%) |
|---|---|---|
| **(110)** | 0.1359 | 0.1374 |
| **(220)** | 0.1705 | 0.1682 |
| **(310)** | 0.1913 | 0.1872 |

**Table S3:** Atomic concentration of the elements.

| Atom | Atomic % in PSk | Atomic% in PSK:PPS |
|---|---|---|
| **C** | 28.09 | 24.54 |
| **O** | 6.15 | 4.46 |
| **I** | 53.01 | 57.8 |
| **Pb** | 12.75 | 13.2 |

**Table S4:** Fitted parameters of TRPL decay in figure 5b.

| Film | A | $\tau_1$ (ns) | B | $\tau_2$(ns) | $\tau_{avg}$ (ns) |
|---|---|---|---|---|---|
| **Psk** | 0.78663 | 2.92794 | 0.56691 | 11.95355 | 9.664089 |
| **Psk:PPS** | 0.48183 | 23.87487 | 0.14917 | 78.20074 | 51.22724 |

**Table S5:** Fitted parameters of TRPL decay in figure S10(b)

| Film | A | $\tau_1$ (ns) | B | $\tau_2$(ns) | $\tau_{avg}$ (ns) |
|---|---|---|---|---|---|
| **SnO2/Psk:PPS** | 141.41 | 164 | 1772.6 | 26.6 | 71.89951 |
| **SnO2/PPS(0.2%)/Psk:PPS** | 269.8 | 138 | 3059.3 | 35.5 | 61.6683 |

**Table S6:** $SnO_2$/Psk, $SnO_2$/Psk:PPS(0.4%), and $SnO_2$/PPS(0.2%)/Psk:PPS(0.4%) Photodetector device results obtained from I-V.

| | $I_L$ (A) | $I_D$ (A) | Responsivity A/W | On/off | Detectivity (J) | Rise/Decay time (sec) |
|---|---|---|---|---|---|---|
| $SnO_2$/Psk | $4.08 \times 10^{-7}$ | $1.32 \times 10^{-10}$ | 3.26 | $3.0 \times 10^3$ | $5.62 \times 10^{12}$ | 1.00/1.12 |
| $SnO_2$/Psk:PPS(0.4%) | $6.58 \times 10^{-7}$ | $8.12 \times 10^{-11}$ | 5.27 | $8.1 \times 10^3$ | $1.15 \times 10^{13}$ | 0.98/0.73 |
| $SnO_2$/PPS(0.2%)/Psk:PPS(0.4%) | $7.41 \times 10^{-7}$ | $6.05 \times 10^{-11}$ | 5.93 | $1.2 \times 10^4$ | $1.51 \times 10^{13}$ | 0.74/0.09 |

**Table S7:** The photodetector device results obtained by performing I-V measurements at various concentrations of PPS incorporation in the perovskite layer and on bare $SnO_2$.

| | $I_L$ (A) | $I_D$ (A) | Responsivity A/W | On/off | Detectivity (J) |
|---|---|---|---|---|---|
| $SnO_2$/Psk | $4.08 \times 10^{-7}$ | $1.32 \times 10^{-10}$ | 3.26 | $3.0 \times 10^3$ | $5.62 \times 10^{12}$ |
| $SnO_2$/Psk:PPS(0.2%) | $5.06 \times 10^{-7}$ | $9.69 \times 10^{-11}$ | 4.04 | $5.2 \times 10^3$ | $8.12 \times 10^{12}$ |
| $SnO_2$/Psk:PPS(0.4%) | $6.58 \times 10^{-7}$ | $8.12 \times 10^{-11}$ | 5.27 | $8.1 \times 10^3$ | $1.15 \times 10^{13}$ |
| $SnO_2$/Psk:PPS(0.6%) | $4.64 \times 10^{-7}$ | $9.15 \times 10^{-11}$ | 3.71 | $5.0 \times 10^3$ | $7.66 \times 10^{12}$ |

**Table S8:** The photodetector device results obtained by performing I-V measurements at various concentrations of PPS interlayer with pristine perovskite.

| | $I_L$ (A) | $I_D$ (A) | Responsivity A/W | On/off | Detectivity (J) |
|---|---|---|---|---|---|
| $SnO_2$/Psk | $4.08 \times 10^{-7}$ | $1.32 \times 10^{-10}$ | 3.26 | $3.0 \times 10^3$ | $5.62 \times 10^{12}$ |
| $SnO_2$/PPS(0.1%)/Psk | $4.55 \times 10^{-7}$ | $9.42 \times 10^{-11}$ | 3.64 | $4.8 \times 10^3$ | $7.40 \times 10^{12}$ |
| $SnO_2$/PPS(0.2%)/Psk | $4.64 \times 10^{-7}$ | $8.67 \times 10^{-11}$ | 3.71 | $5.3 \times 10^3$ | $7.88 \times 10^{12}$ |
| $SnO_2$/PPS(0.4%)/Psk | $4.49 \times 10^{-7}$ | $1.08 \times 10^{-10}$ | 3.59 | $4.1 \times 10^3$ | $6.82 \times 10^{12}$ |

**Table S9:** The photodetector device results obtained by performing I-V measurements at various concentrations of PPS interlayer with PPS incorporated (0.4%) perovskite.

| | $I_L$ (A) | $I_D$ (A) | Responsivity A/W | On/off | Detectivity (J) |
|---|---|---|---|---|---|
| $SnO_2$/Psk | $4.08 \times 10^{-7}$ | $1.32 \times 10^{-10}$ | 3.26 | $3.0 \times 10^3$ | $5.62 \times 10^{12}$ |
| $SnO_2$/Psk:PPS(0.4%) | $6.58 \times 10^{-7}$ | $8.12 \times 10^{-11}$ | 5.27 | $8.1 \times 10^3$ | $1.15 \times 10^{13}$ |
| $SnO_2$/PPS(0.1%)/Psk:PPS(0.4%) | $7.01 \times 10^{-7}$ | $7.17 \times 10^{-11}$ | 5.60 | $9.7 \times 10^3$ | $1.31 \times 10^{13}$ |
| $SnO_2$/PPS(0.2%)/Psk:PPS(0.4%) | $7.41 \times 10^{-7}$ | $6.05 \times 10^{-11}$ | 5.93 | $1.2 \times 10^4$ | $1.51 \times 10^{13}$ |
| $SnO_2$/PPS(0.4%)/Psk:PPS(0.4%) | $5.31 \times 10^{-7}$ | $9.71 \times 10^{-11}$ | 4.24 | $5.4 \times 10^3$ | $8.52 \times 10^{12}$ |