Supporting Information

Luminescent down-shifting $CsPbBr_3$ perovskite nanocrystal for flexible $Cu(In,Ga)Se_2$ solar cells

Ye-Chan Kim,[†] Ho-Jung Jeong,[‡] Sung-Tae Kim,[†] Young Hyun Song,[‡] Bo Young Kim,[‡] Jae Pil Kim,[‡] Bong Kyun Kang,[§] Ju-Hyung Yun,[‖] Jae-Hyung Jang [*†]

† School of Electrical Engineering and Computer Science, Gwangju Institute of Science and Technology, Gwangju 500-712, Republic of Korea,

‡ Lighting Materials and Components Research Center, Korea Photonics Technology Institute, Gwangju 61007, Republic of Korea

§ Nano Materials and Components Research Center, Korea Electronics Technology Institute, Seongnam 463-816, Republic of Korea

‖ Department of Electrical Engineering, Incheon National University, Yeonsu-gu, Incheon 406-772, Republic of Korea

Corresponding Author

Jae-Hyung Jang

* E-mail: jjang@gist.ac.kr

Crystallinity of $CsPbBr_3$ perovskite nanocrystals

To confirm the crystallinity of $CsPbB_{r3}$ perovskite nanocrystals, X-ray diffraction (XRD) pattern was measured by using X-ray diffractometer (X'pert PRO, PAnalitical). The XRD pattern of the $CsPbBr_3$ perovskite nanocrystals is shown in Figure S1 of $CsPbBr_3$ structure. The three strong peaks of (101), (121), and (202) are observed at 15.14°, 21.40°, and 30.70°, respectively. Considering that the XRD pattern is well matched with JCPDS 18-0364, the $CsPbBr_3$ perovskite nanocrystals in this study are highly crystalized.

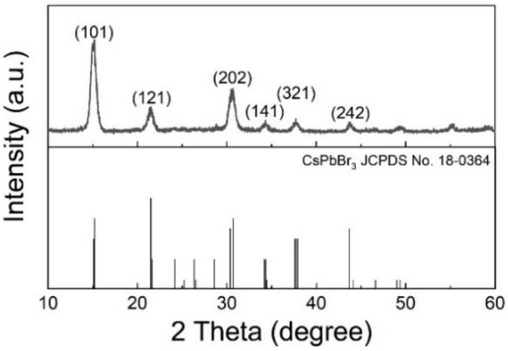

Figure S1. XRD pattern of $CsPbBr_3$ perovskite nanocrystals

Optical transmittance of $CsPbBr_3$ perovskite

The optical transmittance of the 760-nm-thick $CsPbBr_3$ perovskite on top of borosilicate glass was measured by using UV−VIS−IR spectrophotometer. The transmittance of the $CsPbBr_3$ perovskite in Figure S2 shows that it is higher than 90% in long wavelength range between 520 and 1200 nm, but it decreases to 38% in wavelength range shorter than 520 nm due to the light absorption by $CsPbBr_3$ perovskite.

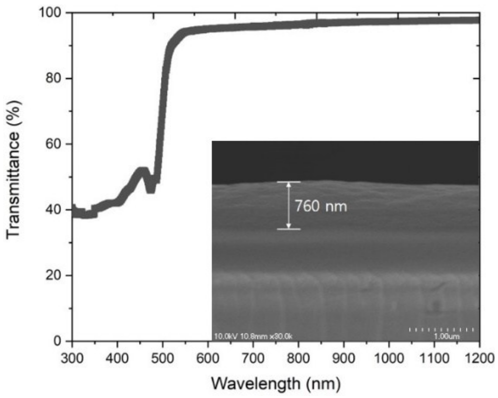

Figure S2. The optical transmittance of the 760-nm-thick $CsPbBr_3$ perovskite. The inset figure shows the cross sectional SEM image of the $CsPbBr_3$ perovskite thin film on top of borosilicate glass.

Refractive index spectrum of $CsPbBr_3$ perovskite

The refractive index of the $CsPbBr_3$ perovskite was measured by using ellipsometer (Uvisel, HORIVA). The measured refractive index of the $CsPbBr_3$ perovskite is shown in Figure S3. Refractive index decreases as the wavelength increases beyond 500 nm and reaches 1.82 at wavelength of 800 nm. From the refractive index spectrum, it was confirmed that $CsPbBr_3$ perovskite luminescent down-shifting (LDS) layer act as an anti-reflection coating because the refractive index of $CsPbBr_3$ perovskite is lower than that of ZnO based transparent conductive oxide (TCO) layer at wavelengths longer than 500 nm[1].

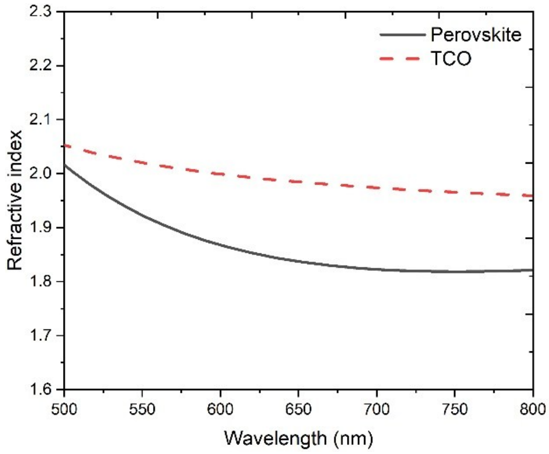

Figure S3. Refractive index spectra of the $CsPbBr_3$ perovskite and TCO layer.

Comparison of surface reflectance spectra of the flexible CIGS solar cell with and without $CsPbBr_3$ perovskite LDS layer

The surface reflectance spectra of the flexible CIGS solar cell with and without $CsPbBr_3$ perovskite LDS layer are compared in Figure S4. Surface reflectance of the flexible CIGS solar cell with $CsPbBr_3$ perovskite LDS layer is reduced in the wavelength range between 333 nm and 1072 nm compared to that of the conventional flexible CIGS solar cell without LDS layer.

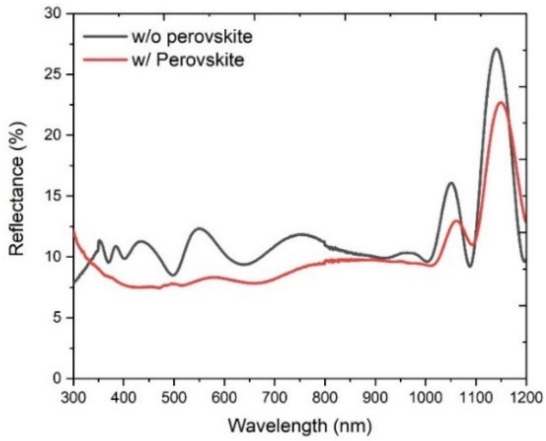

Figure S4. Surface reflectance spectra of the flexible CIGS solar cell with and without $CsPbBr_3$ perovskite nanocrystals

Reference

1 W. L. Bond, J. Appl. Phys., 1965, 36(5), 1674-1677.