Electronic Supplementary Material (ESI) for Nanoscale Advances.
This journal is © The Royal Society of Chemistry 2020

Electronic Supplementary Information

Enhancement of Organic Solar Cell Performance by Incorporating Gold Quantum Dots (AuQDs) on a Plasmonic Grating

Sopit Phetsang,[ab] Supeera Nootchanat,[a] Chutiparn Lertvachirapaiboon,[a] Ryousuke Ishikawa,[a†] Kazunari Shinbo,[a] Keizo Kato,[a] Pitchaya Mungkornasawakul,[b] Kontad Ounnunkad*[bc] and Akira Baba*[a]

[a]Graduate School of Science and Technology, Niigata University, 8050 Ikarashi-2-nocho, Nishi-ku, Niigata 950-2181, Japan.

E-mail: ababa@eng.niigata-u.ac.jp

[b]Department of Chemistry and Center of Excellence for Innovation in Chemistry (PERCH-CIC), Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand

E-mail: kontad.ounnunkad@cmu.ac.th

[c]Center of Excellence for Innovation in Chemistry, Faculty of Science, Center of Excellence in Materials Science and Technology, and Research Center on Chemistry for Development of Health Promoting Products from Northern Resources, Chiang Mai University, Chiang Mai 50200, Thailand

[†]Present Addresses: Advanced Research Laboratories, Tokyo City University, 8-15-1 Todoroki, Setagaya-ku, Tokyo 158-0082, Japan

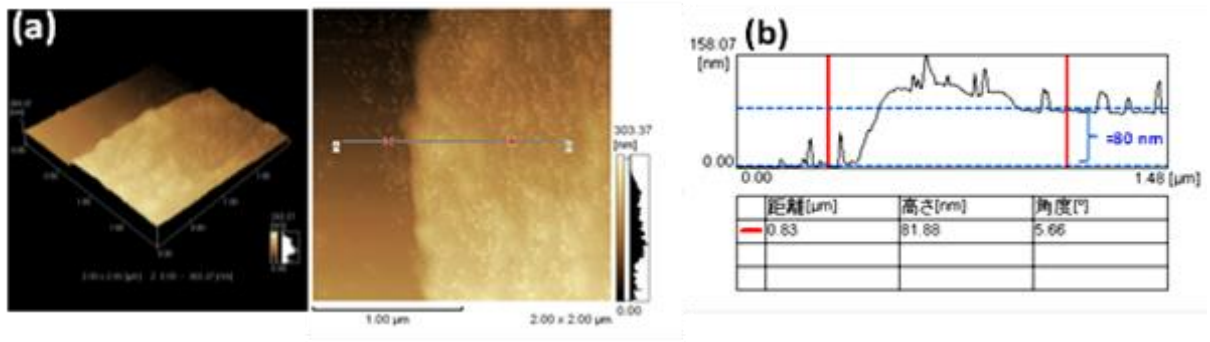

Figure S1. (a) AFM image and (b) a corresponding cross-section profile of a green-AuQD-loaded PEDOT:PSS film cast on an ITO substrate. The thickness of the film is ~80 nm.

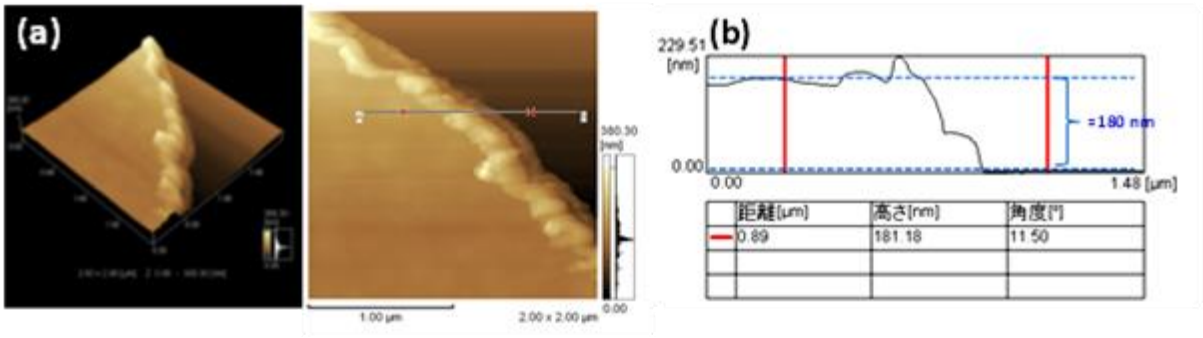

Figure S2. (a) AFM image and (b) a corresponded cross-section profile of a green-AuQD-loaded PEDOT:PSS/P3HT:PCBM film cast on an ITO substrate. The thickness of the AuQD-loaded PEDOT:PSS/P3HT:PCBM film is ~180 nm. Because the thickness of green-AuQD-loaded PEDOT:PSS was ~80 nm (Figure S1), the thickness of the P3HT:PCBM film was ~100 nm.

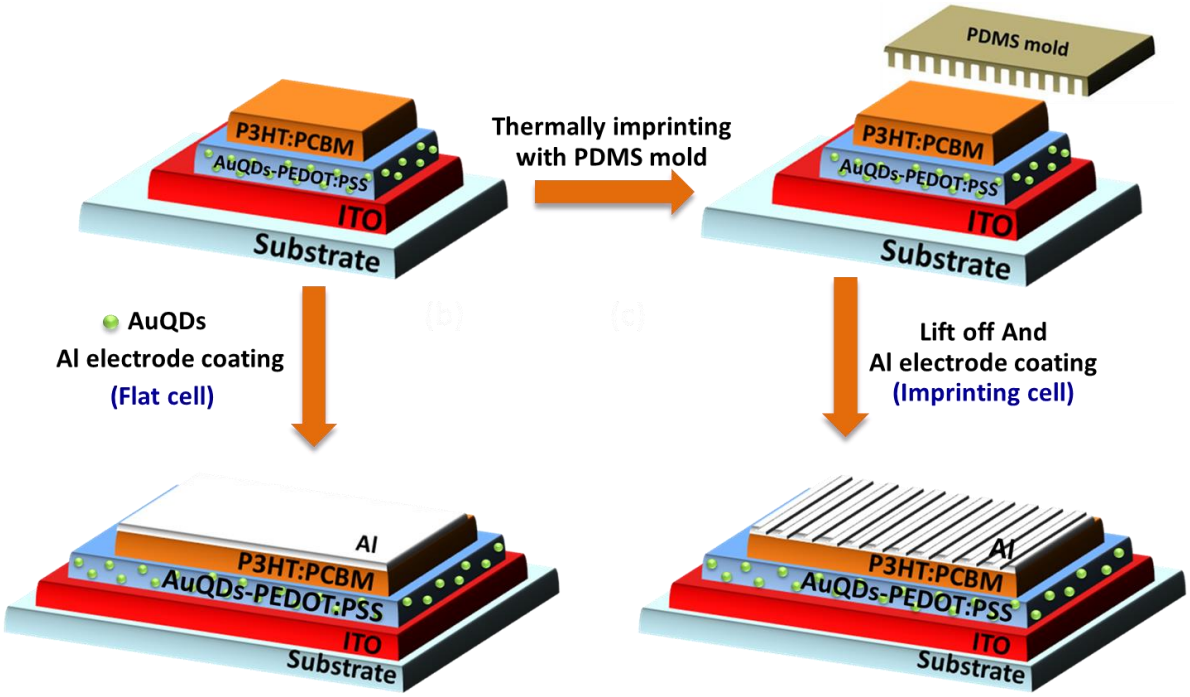

Figure S3. Schematic diagram of the OSC fabrication process

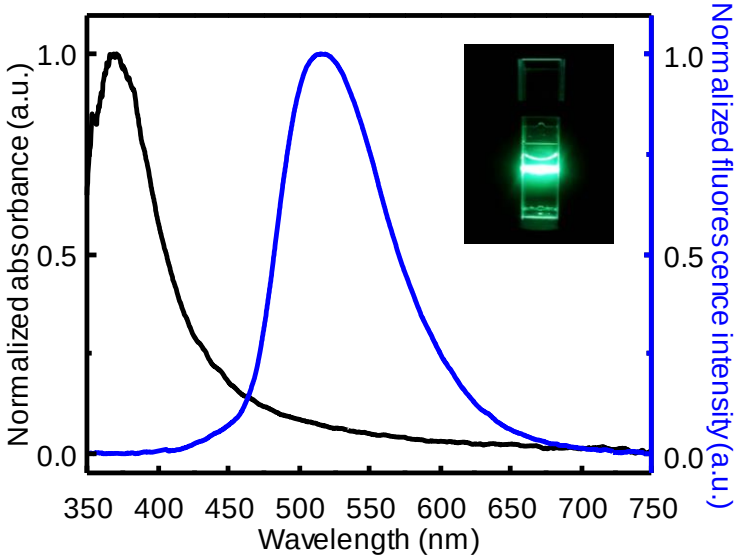

Figure S4. UV-Vis absorption and a fluorescence spectrum of a green-AuQD solution. The insert shows the green fluorescent light generated by green-AuQDs under the irradiation of a violet-blue LASER (405 nm, 20 mW)

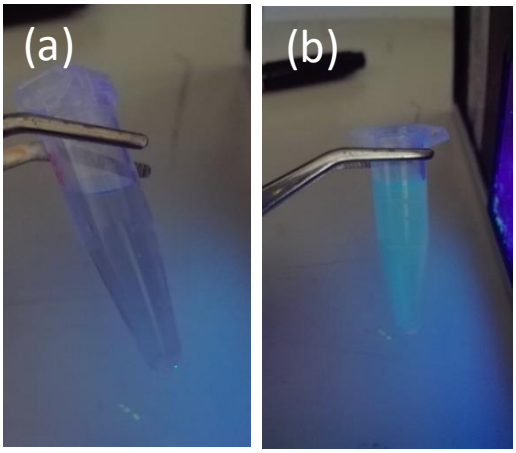

Figure S5. Digital photographs of (a) PEDOT:PSS and (b) green-AuQD-loaded PEDOT:PESS under the UV light illumination. Because the color of PEDOT:PSS is dark blue, the solutions were diluted by 100 times from those which were used for spin coating to clearly observe fluorescence. The total concentration of green-AuQDs in (b) was 0.4.3 μM.

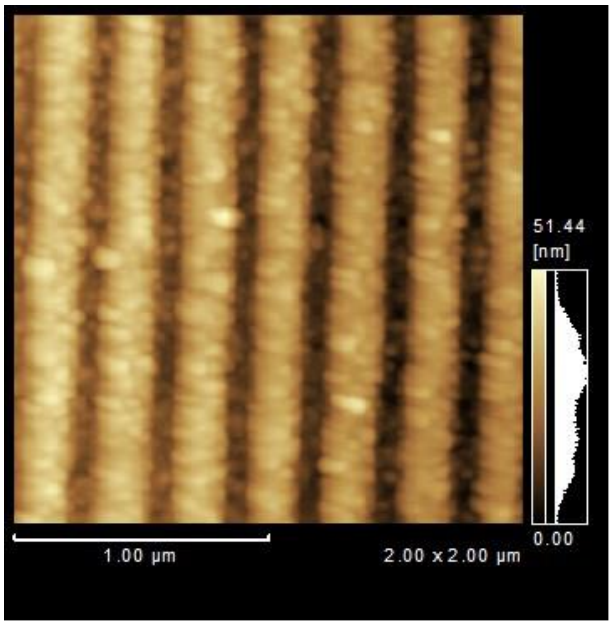

Figure S6. AFM image of the aluminum back electrode in a BD-R OSC.

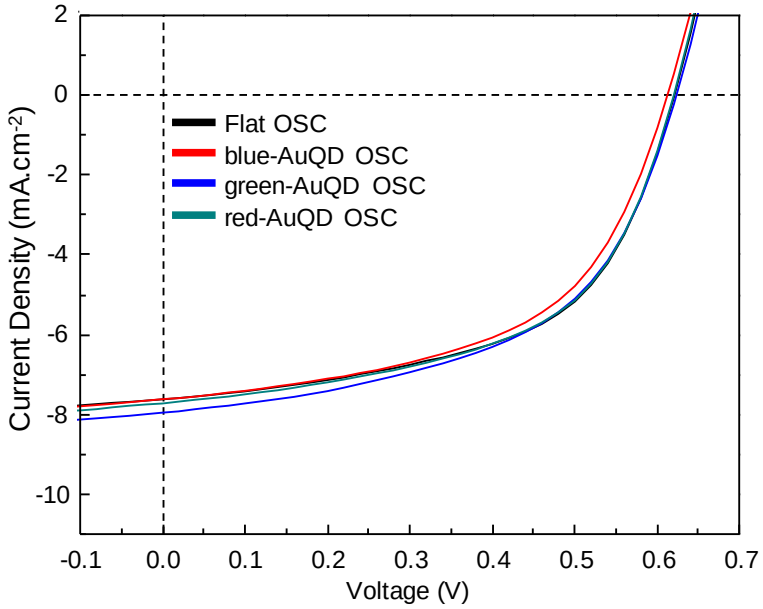

Figure S7. *J–V* characteristics of the AuQD-loaded OSCs under the illumination with an intensity of 75 mW/cm^2. The OSCs were illuminated at the normal incidence angle.

Table S1. Electrical parameters of AuQD-loaded OSCs under the illumination with an intensity of 75 mW/cm^2. The OSCs were illuminated at the normal incidence angle.

Devices	Electrical parameters				
	J_{sc} (mA.cm^{-2})	V_{oc} (Vol)	*FF* (%)	IPCE (%)	IPCE enhancement (%)
Flat OSC	7.37±0.08	0.61	0.54	3.27±0.03	-
blue-AuQD OSC	7.57±0.15	0.62	0.53	3.31±0.02	1.22
green-AuQD OSC	7.83±0.07	0.62	0.54	3.54±0.04	8.26
red-AuQD OSC	7.61±0.04	0.62	0.54	3.49±0.03	6.73

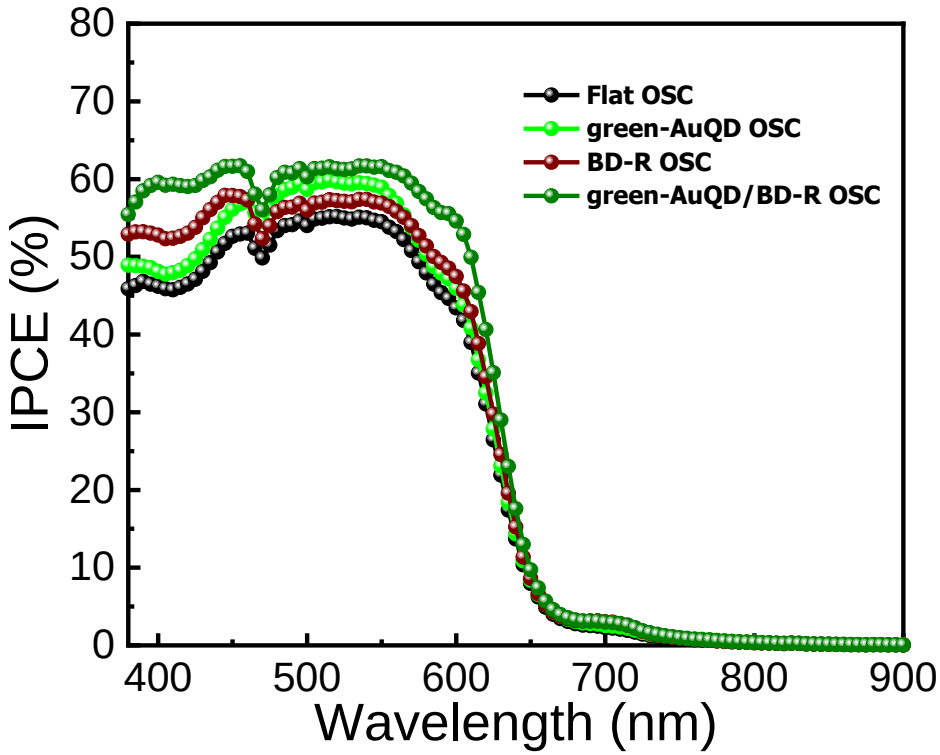

Figure S8. Incident photon-to-current efficiency (IPCE) spectra of fabricated OSCs measured at 30° under the irradiation of a non-polarized light.

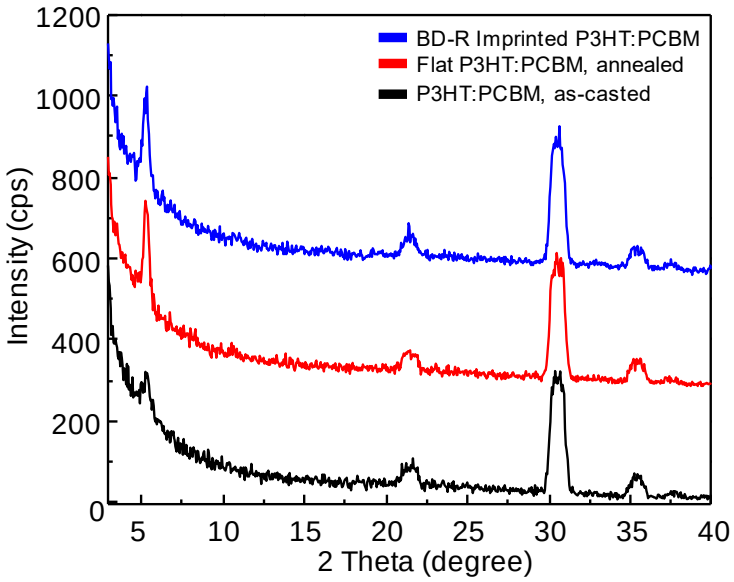

Figure S9. X-ray diffraction (XRD) patterns of the P3HT:PCBM film cast on glass substrates.

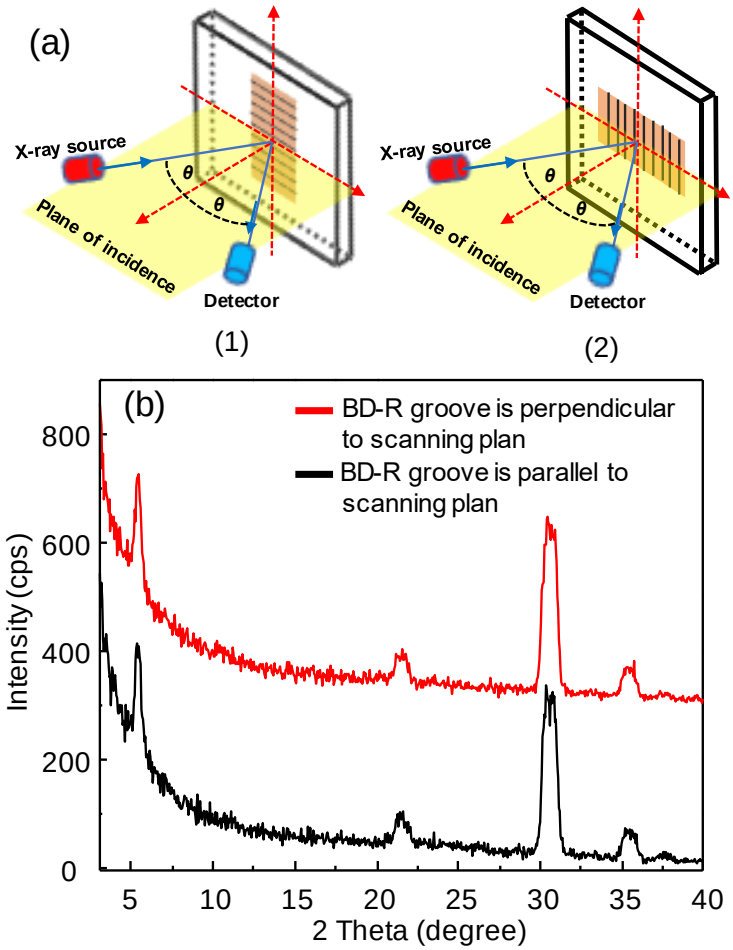

Figure S10. (a) Schematic diagram illustrating the X-ray diffraction (XRD) characterization of BD-R imprinted P3HT:PCBM film with different orientations. (b) XRD patterns of the BD-R imprinted P3HT:PCBM film recorded with a different orientation toward the XRD scanning plane.

Table S2. Average electron lifetime (τ_{avg}) and the maximum frequency (f_{max}) of fabricated OSCs

Devices	f_{max} (kHz)	τ_{avg} (μs)
Flat OSC	63.10	2.52
green-AuQD OSC	63.10	2.52
BD-R OSC	63.10	2.52
green-AuQD/BD-R OSC	63.10	2.52

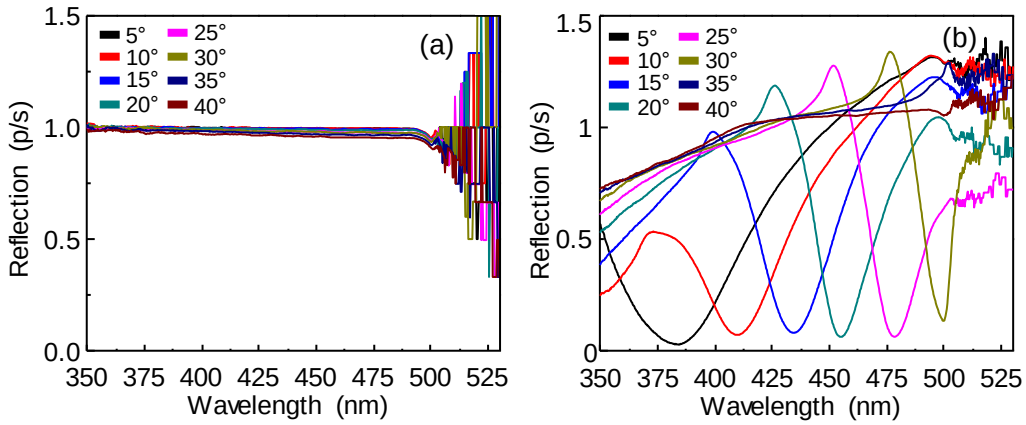

Figure S11. Reflectivity curves (p/s) of a green-AuQD thin film fabricated on an (a) Al-coated glass slide and on an (b) Al-coated BD-R substrate. The reflectivity curves (p/s) were recorded under the illumination in the region of 350–500 nm.