Eliminated hysteresis and stabilized power output over 20% in planar heterojunction perovskite solar cells by compositional and surface modifications to the low-temperature-processed TiO$_2$ layer

Feilong Cai$^{a,b}$, Liyan Yang$^{a,b}$, Yu Yan$^{a,b}$, Jinhui Zhang$^{a,b}$, Fei Qin$^c$, Dan Liu$^{a,b}$, Yi-Bing Cheng$^{d,e}$, Yinhua Zhou$^c$, Tao Wang$^{a,b,*}$

$^a$State Key Laboratory of Silicate Materials for Architectures, Wuhan University of Technology, Wuhan, 430070, China
$^b$School of Materials Science and Engineering, Wuhan University of Technology, Wuhan, 430070, China
$^c$Wuhan National Laboratory for Optoelectronics, and School of Optical and Electronic Information, Huazhong University of Science and Technology, Wuhan, 430074, China
$^d$State Key Laboratory of Advanced Technology for Materials Synthesis and Processing, Wuhan University of Technology, Wuhan, 430070, China
$^e$Department of Materials Science and Engineering, Monash University, Victoria 3800, Australia

* E-mail: twang@whut.edu.cn
Figure S1. (a) Photos of the TiO\textsubscript{2} solution without (left) and with (right) the addition of TIPD. (b) Scanning electron microscopy (SEM) image of a TiO\textsubscript{2}:TOPD film cast on ITO substrate. High magnification SEM images of TiO\textsubscript{2} films cast on ITO substrate with (c) and without (d) the addition of TOPD.

Figure S2. Conversion of TIPD to TOPD upon thermal annealing\textsuperscript{1,2}.
Figure S3. The XRD spectra of perovskite on ITO (green line), TiO₂:TOPD (black line), TiO₂:TOPD/PC₆₀BM (red line), TiO₂:TOPD/C₆₀-ETA (blue line) surfaces.

Figure S4. The J-V curves of devices using TiO₂:TOPD/PC₆₀BM as ETLs with (a) 0 nm, (b) 29 nm, (c) 33 nm, (d) 35 nm, (e) 37 nm, (f) 50 nm, respectively. PCEs close to the average values were selected and plotted in this figure.
Figure S5. The $J$-$V$ curves of devices using (a) TiO$_2$:TOPD/PC$_{60}$BM(2nm) and (b) TiO$_2$:TOPD/C$_{60}$-ETA(2 nm) as ETLs, respectively. PCEs close to the average values were selected and plotted here.

Figure S6. The evolutions of PCE as a function of illumination time using (a) 50 nm PC$_{60}$BM and (b) 30 nm PC$_{60}$BM as the ETLs.

Figure S7. (a) The conductivity of TiO$_2$:TOPD/PC$_{60}$BM films with various PC$_{60}$BM thickness. (b) The
conductivity of TiO$_2$:TOPD/C$_{60}$-ETA films with various C$_{60}$-ETA thickness.

Figure S8. (a) The PL spectra of perovskite films on TiO$_2$:TOPD/PC$_{60}$BM with different PC$_{60}$BM thickness. (b) The PL spectra of perovskite films on TiO$_2$:TOPD/C$_{60}$-ETA with different C$_{60}$-ETA thickness.