Electronic Supplementary Information

High performance near infrared phototransistor via enhanced electron trapping effect

Xingyu Jiang[#a], Jie Lu[#a], Di Xue[a], Yujia Wei[a], Yadan Zhang[a], Jidong Zhang[b], Zi Wang[*a], Lizhen Huang[*a], Lifeng Chi[*a]
[a]Institute of Functional Nano & Soft Materials (FUNSOM), Jiangsu Key Laboratory for Carbon-Based Functional Materials & Devices, Soochow University, 199 Ren'ai Road, Suzhou, 215123, Jiangsu, P.R. China
[b] Changchun Institute of Applied Chemistry, CAS

1. Experimental section

Film fabrication and characterization: The heavily doped p-type silicon wafer with a 300 nm thermal oxide SiO_2 layer was used as the substrate. OTS modification was processed to via vacuum deposition approach at 100 °C for 60 mins. Dielectric capacitance is about 11.5 nF/cm^2 for bare and 11 nF/cm^2 for OTS modified SiO_2/Si substrate. DPPDTT and DCV3T were purchased from Lumtec company and used directly. The 6 mg/ml DPPDTT solution with chlorobenzene as solvent was stirred for 60 mins at 60 °C and then spin-coating at a speed of 3000 rpm for 30s to obtain the pure DPPDTT film. DCV3T solution with the same concentration and solvent was fabricated as well. For the blended films, the DPPDTT solution and DCV3T solution were mixed with different ratio by volume and stirred for 30 mins. Then the mixed solution was spin-coated using the same condition. All films were annealed at 90 °C for 30 mins. The AFM images were recorded using the Bruker dimensional Icon system in tapping mode. UV-vis absorption spectrum was conducted via the Lambda 950. The 2D-Grazing incident X-ray diffraction was conducted at Shanghai Synchrotron Radiation Facility.

Device fabrication and measurement: 40 nm thick gold (Au) was thermally deposited as source and drain electrodes on the top of semiconducting film through a shadow mask to form the top-contact bottom gate thin film transistors (W= 1 mm, L= 50 μm). LED source of 740 nm, 850 nm and 940 nm was controlled by the system. The transistor performance was measured using the Keithley 4200SCS integrated with a lakeshore vacuum probe station. During measurement, the device is in ambient condition. Phototransistor parameter calculation was performed according to the following equations.

$$R = (I_{ill} - I_{dark})(P_i A)^{-1} \quad (1)$$

$$D^* = \frac{RA^{\frac{1}{2}}}{(2qI_{dark})^{\frac{1}{2}}} \quad (2)$$

$$P = \frac{I_{ph}}{I_{dark}} = \frac{I_{ill} - I_{dark}}{I_{dark}} \quad (3)$$

of which the I_{ill} and I_{dark} represent the I_D current under illumination and in dark, P_i is the light power intensity, A is the channel area, q is elementary charge of electron. D* is using the one that only put shot noise in consideration.

2. Additional data

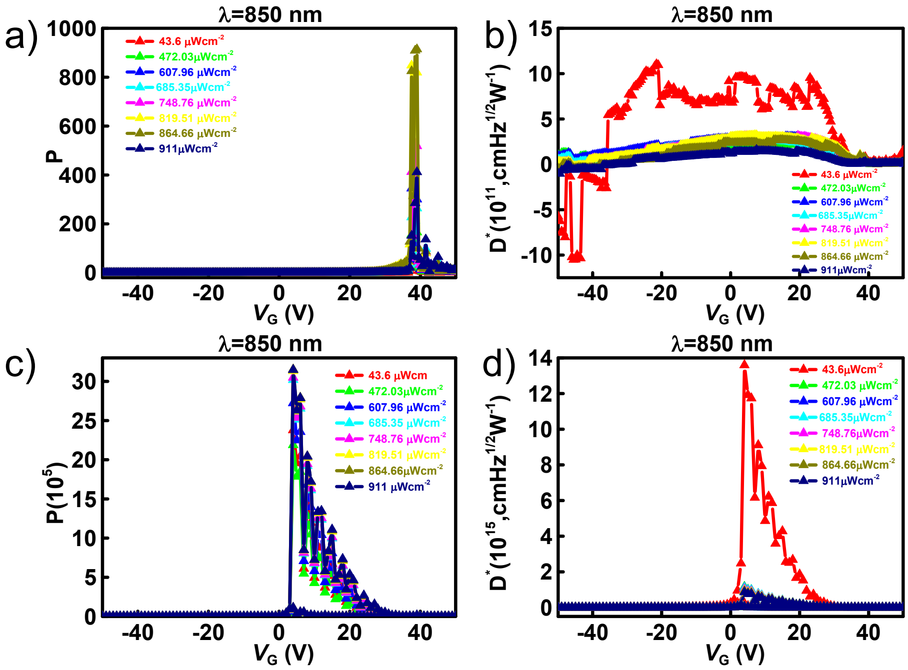

Figure S1. The photosensitivity and detectivity plot with gate voltage for pure DPPDTT (a-b) and DPPDTT:DCV3T(9:1)

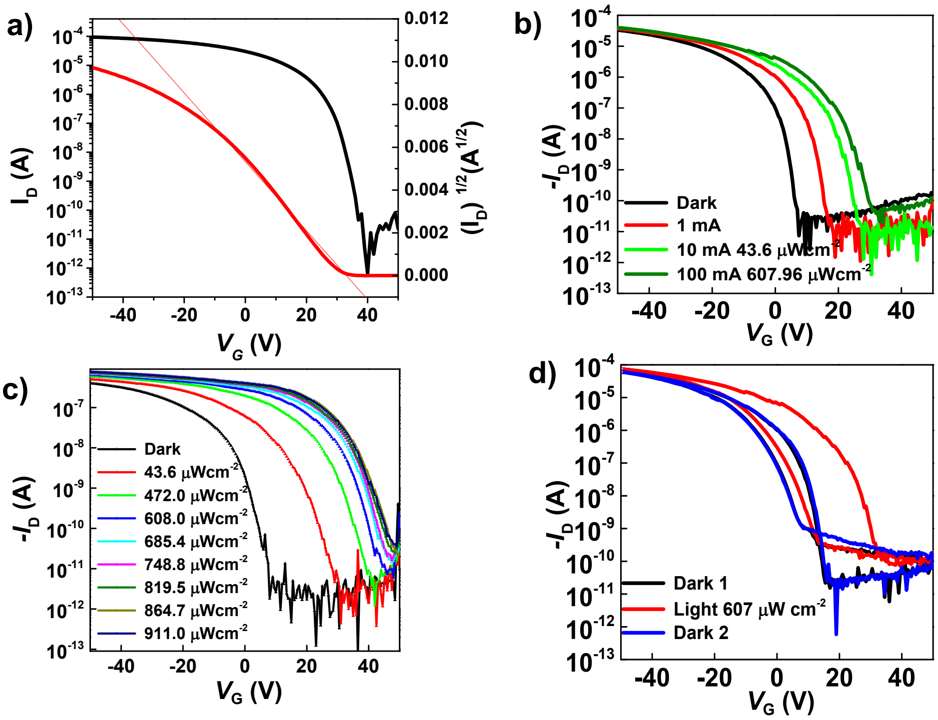

Figure S2. a) the transfer and $I_D^{1/2}$ vs gate voltage plots of DPPDTT:DCV3T (9:1) transistors, the plots indicates that at high negative positive voltage, the device charge mobility is reduced. b) the transfer curve evolution upon illumination by the light with operation current from 1 mA to 100 mA of DPPDTT:DCV3T (9:1) on OTS modified substrate. c) The photoresponse of DPPDTT:DCV3T (9:1) on bare Si/SiO_2 substrate, a clearly gradual shift of the V_T and current increment was observed upon illumination by 850 nm light with different power intensity. d) transfer curve of a testing cycle from the initial dark, the first illumination and then the second dark state. After illumination, the transfer of dark condition recovers to the level of the initial dark condition.

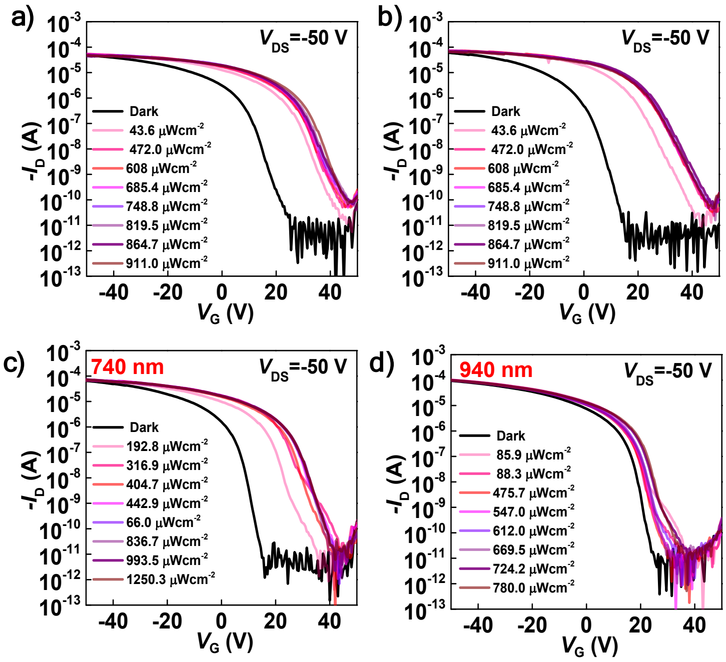

Figure S3. Transfer curve evolution of a) DPPDTT:DCV3T (3:1) and b) DPPDTT:DCV3T (1:1) film upon illumination by 850 nm; Transfer curve evolution of DPPDTT:DCV3T(9:1) upon illumination by c) 740 nm and d) 940 nm.

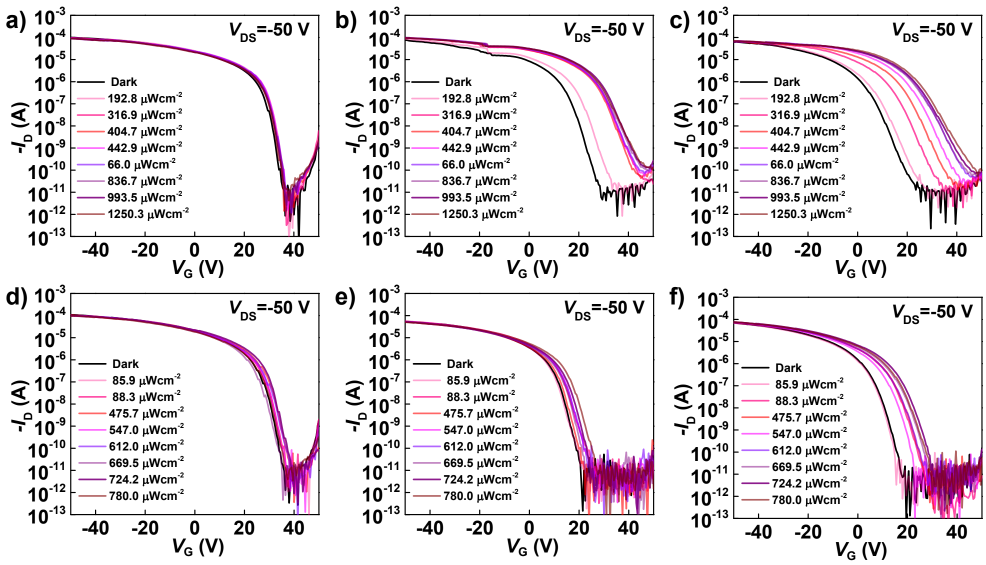

Figure S4. transfer curve evolution upon light irradiation at 740 nm (a-c) and 940 nm (d-f) of a, d) pure DPPDTT, (b, e) DPPDTT:DCV3T(3:1); (c, f) DPPDTT:DCV3T(1:1).

Table S1. Performance comparison of our work and typical organic NIR phototransistors reported previously.

Materials	Morph-ology	Light/power	R (AW^{-1})	P_{max}	D^* (Jones)	Ref.
TFT-CN	2D single crystal	808 nm / (2.5 μWcm^{-2})	$9*10^4$	$5*10^5$	$6*10^{14}$	Adv. Mater. 2018, 30, 1706260
PDPPBTT: PCBM	Films	820 nm / (0.031 mWcm^{-2})	$5.26*10^3$	10^6	$8.21*10^{16}$	Adv. Opt. Mater. 2021, 9, 2002031
BODIPY	Films	850 nm / (0.5 mWcm^{-2})	$1.14*10^4$	$1.04*10^4$	-------	Adv Electron Mater. 2017, 3, 1600430
DPPDTT: PCBM	Films	808 nm / (67 nW cm^{-2})	$8*10^5$	$3*10^4$	$3.5*10^{12}$	Nanoscale, 2013, 5, 11850
CuPc/PbPc :PTCDA	Films	808 nm / (1 mW cm^{-2})	0.322	$9.4*10^2$	---------	Org. Electron. 2013, 14, 1045
PDIBDF-TT	Nano wire	808 nm / (47 mWcm^{-2})	0.44	$3.3*10^4$	---------	Nanoscale, 2016, 8, 7738
PDVT: PCBM	Films	760 nm / (20 μWcm^{-2})	$5.7*10^5$	$5*10^7$	$1.15*10^{18}$	ACS Mater. Interface, 2021, 13, 1035
PQT-12/ F_4-TCNQ	Films	2000 nm / (90 μWcm^{-2})	$2.75 *10^6$	$6.8*10^5$	$3.12*10^{14}$	Adv. Funct. Mater. 2021, 2103787
DPPDTT: DCV3T (9:1)	Film	850 nm / (43 μWcm^{-2})	$2*10^3$	$3*10^6$	$1.4*10^{16}$	This work

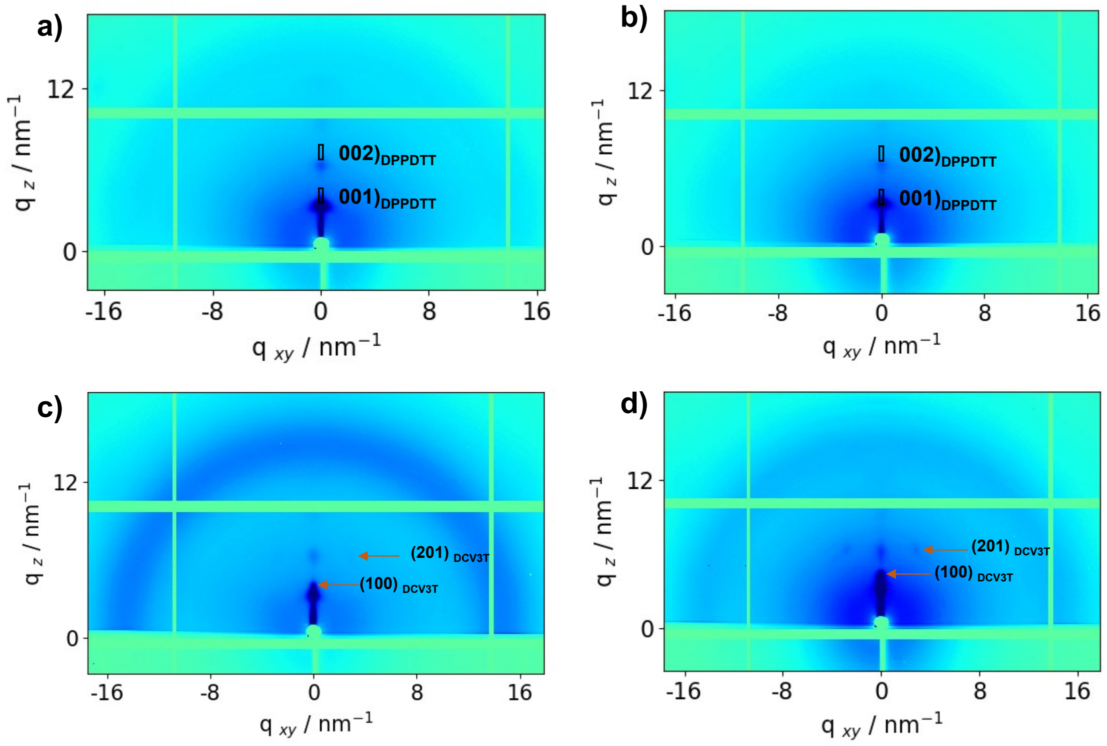

Figure S5. 2D-GIWAXS of pure DPPDTT and the DPPDTT:DCV3T blending films. a) pure DPPDTT, b) DPPDTT:DCV3T (9:1), c) DPPDTT:DCV3T (3:1), d) DPPDTT:DCV3T (1:1).