Supplemental Material to the article "Spatially localized photoeffect in ambipolar organic field-effect phototransistors"

Phototransistor model. The bound electron-hole pair dissociation rate k_{diss} is determined by the following formula, which was used in the model of organic solar cells with a bulk heterojunction [12]:

$$k_{\text{diss}}(a,E) = \frac{3\alpha}{4\pi a^3} \exp\left\{-\frac{e^2}{\varepsilon\varepsilon_0 akT}\right\} \cdot \frac{J_1(2\sqrt{-2b})}{\sqrt{-2b}}, \quad b = \frac{e^3|E|}{8\pi\varepsilon\varepsilon_0 k^2T^2}, \tag{S1}$$

where a – separation distance of bound e/h-pair, α – Langevin bimolecular recombination constant (see below), e – electron charge, ε – active layer dielectric constant, ε_0 – electric constant, k – Boltzmann constant, T – temperature, J_1 – first order Bessel function. The probability of bound e/h-pair dissociation is determined by formula:

$$p(a,E) = \frac{k_{\text{diss}}(a,E)}{k_{\text{diss}}(a,E) + k_f}. \tag{S2}$$

Because organic semiconductors tend to disorder, in model it is proposed that separation distances of bound e/h-pairs are not constant throughout the system, therefore expression for bound e/h-pair dissociation probability has form:

$$P(E) = \int_0^\infty p(a,E) f(a,a_0) da, \tag{S3}$$

where $f(a,a_0)$ – is distribution function:

$$f(a,a_0) = \frac{4}{\sqrt{\pi}a_0^3} a^2 \exp\left(-\frac{a^2}{a_0^2}\right). \tag{S4}$$

The main equations of model are Poisson equation for electric potential φ:

$$\frac{d^2\varphi}{dx^2} = \frac{e}{\varepsilon\varepsilon_0}[p(x) - n(x)] + \frac{C_s}{\varepsilon\varepsilon_0 d}[\varphi(x) - V_G], \tag{S5}$$

continuity equations for electron and hole current densities j_n and j_p:

$$\frac{dj_p}{dx} = eP(E)G(x) - e(1 - P(E))R(x), \tag{S6}$$

$$-\frac{dj_n}{dx} = eP(E)G(x) - e(1 - P(E))R(x), \tag{S7}$$

relations describing drift and diffusion of electrons and holes:

$$j_p(x) = e\mu_p p(x)\frac{d\varphi}{dx} - \mu_p kT\frac{dp}{dx}, \tag{S8}$$

$$j_n(x) = e\mu_n n(x)\frac{d\varphi}{dx} + \mu_n kT\frac{dp}{dx}, \tag{S9}$$

where $p(x)$ and $n(x)$ are free holes and electrons concentrations, C_S is gate-dielectric-active layer electric capacitance per area, d is thickness of current conducting layer, V_G is gate voltage, μ_p is hole mobility, μ_n is electron mobility, $G(x)$ is bound e/h-pairs generation rate under incident radiation, $R(x)$ is charge carrier recombination rate. In this work the bimolecular Langevin recombination is considered:

$$R(n) = \alpha[n(x)p(x) - n_0 p_0]. \tag{S10}$$

Charge carrier recombination constant is determined by Langevin formula:

$$\alpha = \frac{e(\mu_n + \mu_p)}{\varepsilon\varepsilon_0}. \tag{S11}$$

System of equations (S5)–(S9) is complemented by boundary conditions at contacts with source and drain electrodes at $x = 0$ and $x = L$ for unknown functions $\varphi(x)$, $p(x)$ and $n(x)$. Solving this system at different values of source-drain voltage V_D, which is contained in boundary conditions for electric potential, and source-gate voltage V_G, it is possible to obtain output and transfer characteristics. For numerical solution of this problem the program on language C was written. Numerical values of input parameters are given in Table 1 and correspond to typical values for transistors based on organic semiconductions.

1. Input parameters of model

Parameter	Symbol	Value	Units
Channel length	L	1	μm
Permittivity	ε	2	
Temperature	T	290	K
Electron mobility	μ_n	10^{-3}	$cm^2\,V^{-1}\,s^{-1}$
Hole mobility	μ_p	10^{-3}	$cm^2\,V^{-1}\,s^{-1}$
Channel thickness	d	3	nm
Transistor capacitance per area	C_S	1.8×10^{-3}	F/m^2
Left electrode work function	A_1	5.05	eV
Right electrode work function	A_2	4.05	eV
Electron affinity	χ	4.0	eV
Band gap	E_g	1.1	eV
Separation distance of e/h pair	a_0	1.3	nm
e/h-pair fission rate	k_f	10^4	s^{-1}
e/h-pair generation rate	G_0	10^{30}	$m^{-3}\,s^{-1}$
Density of states in conduction band	N_c	10^{26}	m^{-3}
Density of states in valence band	N_v	10^{26}	m^{-3}

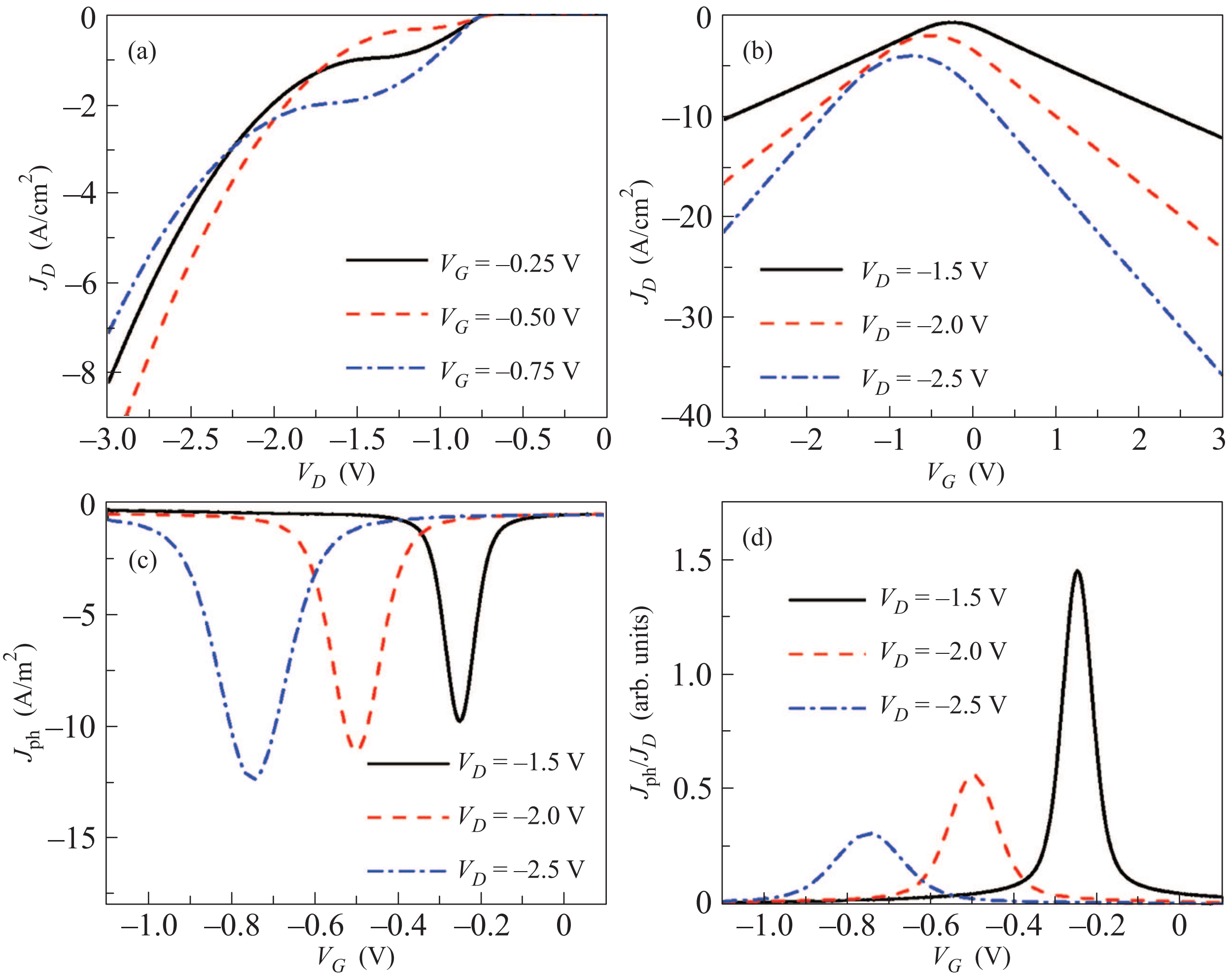

Fig. S1. Output (a) and transfer (b) characteristics of organic field-effect phototransistor. Photocurrent density (difference between current densities under illumination and in dark) (c), and photocurrent to dark current ratio (d) depending on V_G for three different V_D values

Current-voltage characteristics in dark and under illumination. Figure S1 presents output and transfer characteristics, and also photocurrent and photocurrent/dark current ratio dependences on gate voltage V_G under illumination with Gauss-distributed intensity along x axis according to Eq. (4) with full width at half-maximum $w_G = 200$ nm and peak position $x_0 = 500$ nm, i.e. in the middle of channel. Output characteristics are calculated for three different values of V_G, and transfer characteristics are calculated for three different values of V_D.