Supplementary Information

On the factors affecting the response time of synaptic ion-gated transistors

Ramin Karimi Azari*[a], Tian Lan[a], Clara Santato*[a]

[a] Engineering Physics, Polytechnique Montreal, 2500 Ch. Polytechnique, H3T 1J4, Montreal, QC, Canada

Corresponding authors: ramin.karimi@polymtl.ca, clara.santato@polymtl.ca

Morphology and structure of the P3HT films

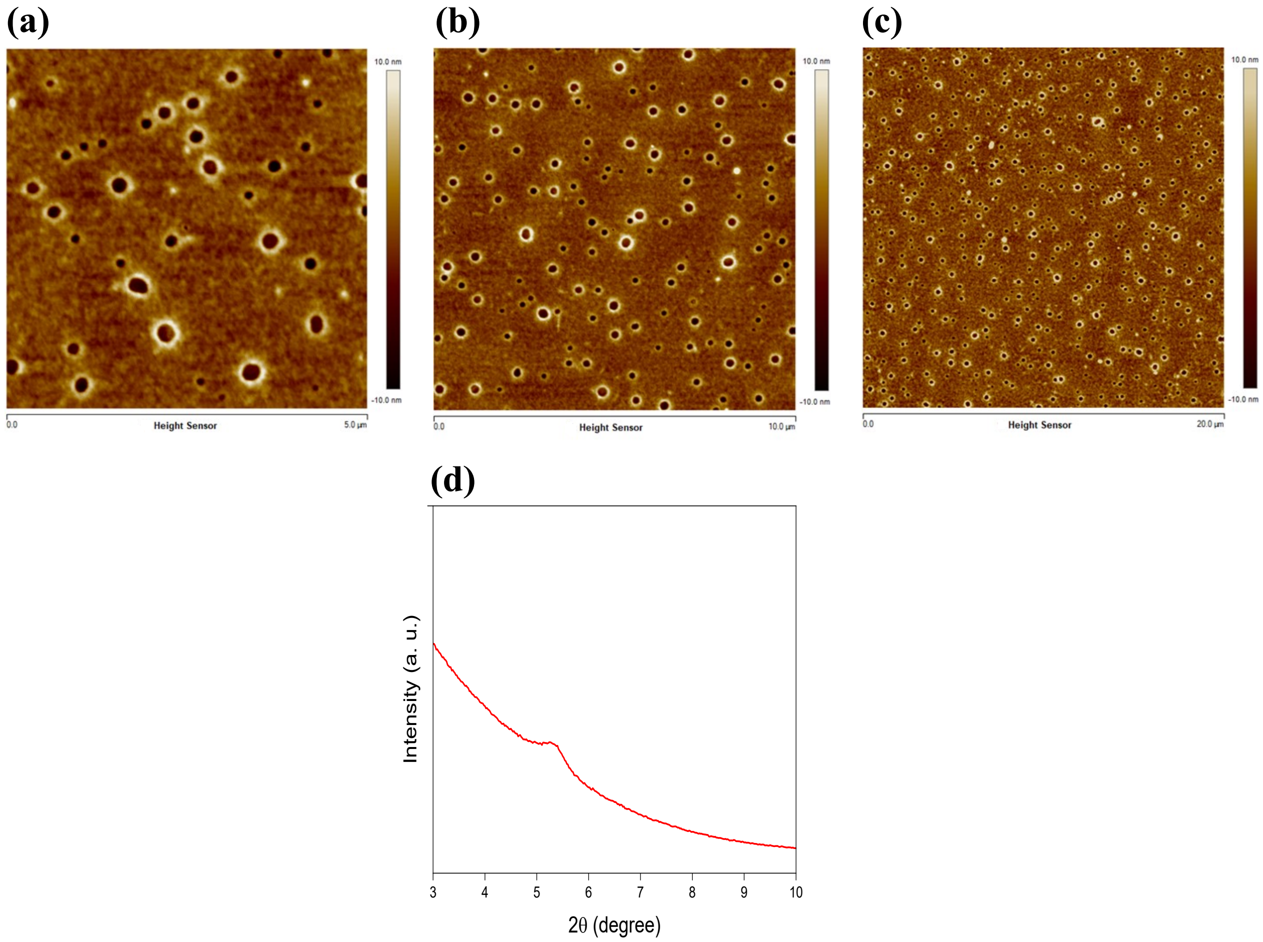

Figure S1 AFM height images of P3HT films with size: **a)** 5 μm×5 μm, **b)** 10 μm×10 μm, **c)** 20 μm×20 μm and **d)** XRD patterns of the P3HT films.

Transfer and output characteristics of IGTs at different V_{gs} scan rates

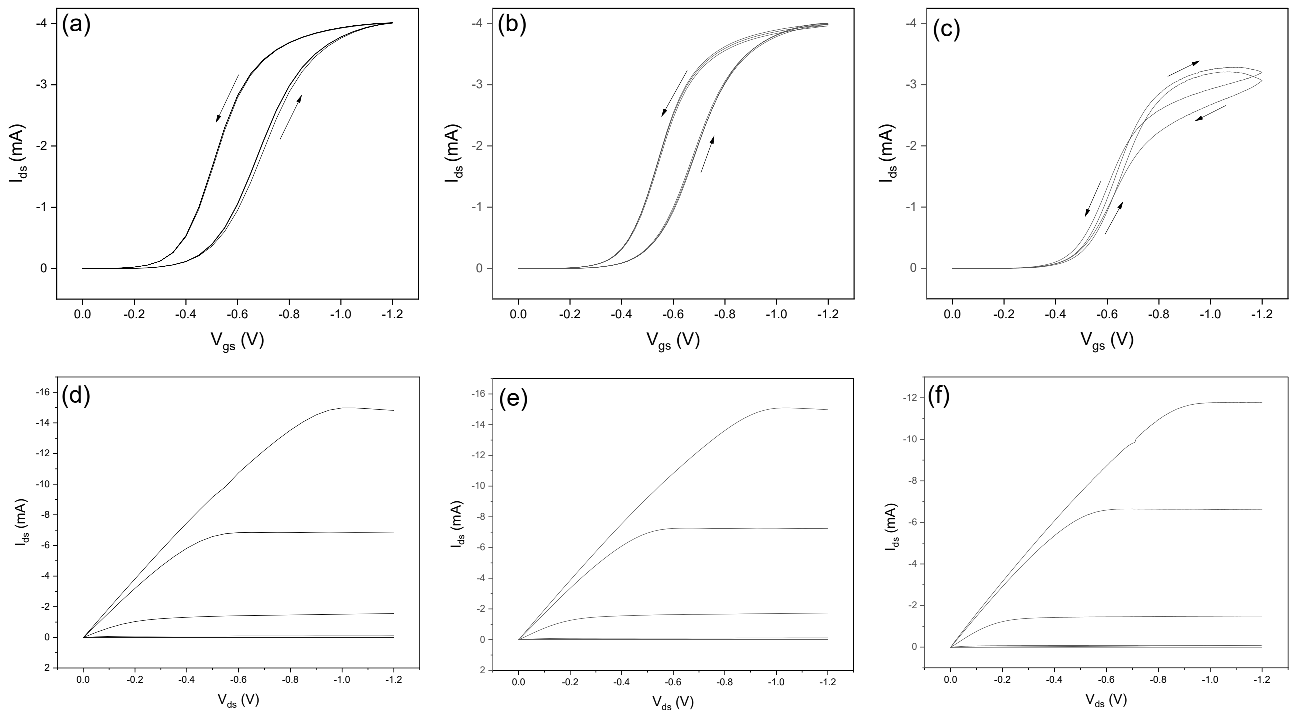

Figure S2 Transfer characteristics of [EMIM][TFSI]-gated P3HT transistors in the linear regime (V_{ds}= -0.2 V (3 cycles)) at V_{gs} scan rates of: **a)** 50 mVs^{-1}, **b)** 25 mVs^{-1} and **c)** 5 mVs^{-1}. Output characteristics with V_{gs}= 0, -0.2, -0.4, -0.6, -0.8, -1 V with V_{ds} scan rates of: **d)** 50 mVs^{-1}, **e)** 25 mVs^{-1}, **f)** 5 mVs^{-1}.

We calculated the charge carrier density (ρ, cm^2) and mobility (μ, $cm^2V^{-1}s^{-1}$) in our P3HT channels from the transfer characteristics with V_{gs} sweeping rates of 5, 25, 50, and 100 mVs^{-1} and V_{ds} = -0.2 V (Table S1).

We obtained the charge carrier density from the equation: $\rho = \frac{Q}{eA} = \frac{\int I_g dV_{gs}}{eAr_v}$, where Q represents the amount of charge accumulated during the forward scan in the transfer curve (resulting from the integration of I_{gs} with V_{gs}), e is the elementary charge, A is the interfaced area of the P3HT film, and the ionic media (4 mm×9 mm), and r_v is the scan rate of V_{gs}. [1]

The charge carrier mobility, μ, is obtained by $\mu = \frac{L\ I_{ds}}{WQV_{ds}}$. [2]

The ON/OFF ratio, calculated from the transfer curves, is the ratio between I_{ds} in the ON state and I_{ds} in the OFF state (I_{on}/I_{off}), calculated for a fixed V_{gs}. The threshold voltage, V_{th}, was calculated using a linear extrapolation of the I_{ds} - V_{gs} curve, in the linear regime. [3]

Table S1 The values of threshold voltage and ON/OFF ratios of [EMIM][TFSI]-gated P3HT transistors (V_{ds}= -0.2 V) at different V_{gs} scan rates:100, 50, 25, and 5 mVs^{-1}.

V_{gs} scan rate (mVs^{-1})	ON/OFF ratios	Threshold voltage (V)	Mobility ($cm^2V^{-1}s^{-1}$)	Charge carrier density (cm^{-2})
100	1.7×10^3	-0.47 ± 0.03	0.26 ± 0.08	$1.3\times10^{15} \pm 0.5\times10^{15}$
50	2.6×10^3	-0.46 ± 0.03	0.19 ± 0.06	$1.7\times10^{15} \pm 0.5\times10^{15}$
25	3.1×10^3	-0.45 ± 0.03	0.14 ± 0.04	$2.1\times10^{15} \pm 0.5\times10^{15}$
5	5.8×10^4	-0.44 ± 0.03	0.06 ± 0.01	$5.7\times10^{15} \pm 0.8\times10^{15}$

Importance of the V_{gs} sampling time on the measurement of the response time

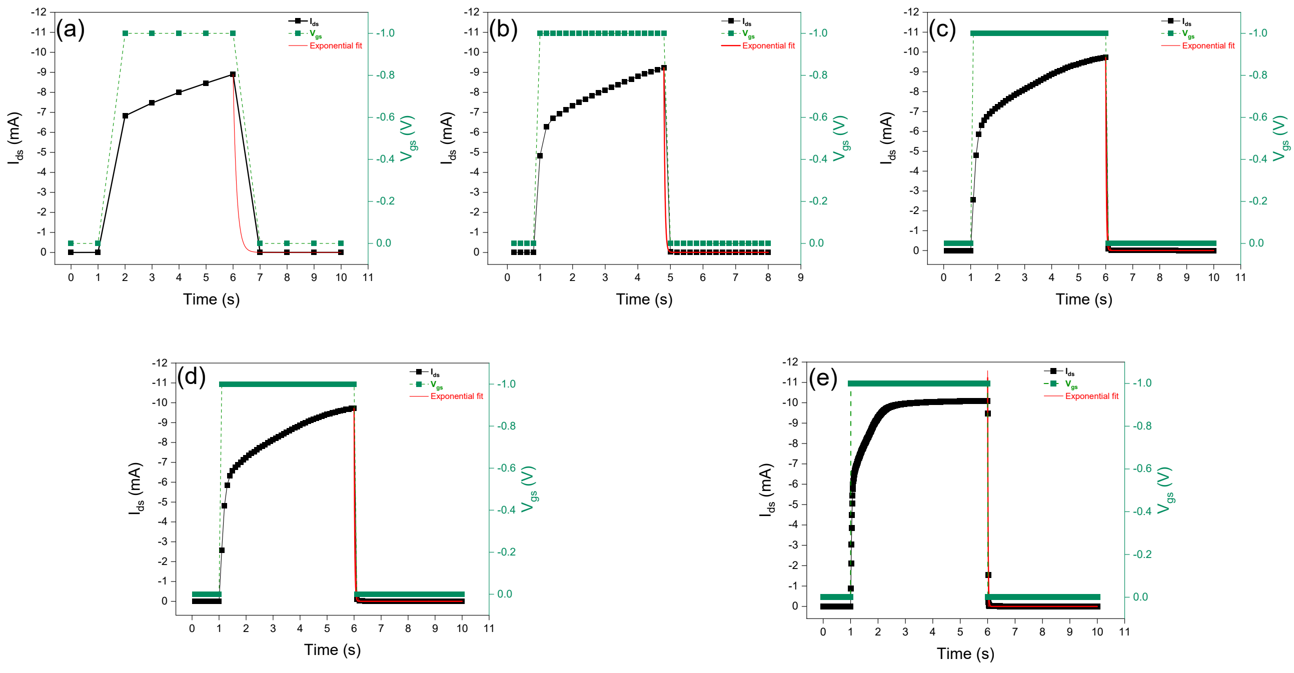

Figure S3 Transient I_{ds} characteristics of [EMIM][TFSI]-gated P3HT transistors at different $V_{gs.}$ pulse sampling times: **a)** 1s, **b)** 250 ms, **c)** 100 ms, **d)** 50 ms, **e)** 10 ms in response to a single V_{gs} = -1 V pulse, with V_{ds}=-0.8 V; the duration of the $V_{gs.}$ pulse is 5 s.

Fitting parameters for exponential fitting curves

R-square, also known as the coefficient of determination, measures a model's goodness of fit. The closer the fit is to the data points, the closer R-square will be to the value of 1.

We report fitting parameters for figures 3-5 in the tables below.

Table S2 R-square parameter values related to exponential fits used to estimate the response time of different numbers of V_{gs} pulses.

Number of V_{gs} pulses	5 pulses	10 pulses	25 pulses
R-square	0.92	0.91	0.91

Table S3 R-square parameter values related to exponential fits used to estimate the response time of different duration time of pulse.

Duration time of V_{gs} pulse	10 ms	100 ms	500 ms	1 s	5 s	9 s
R-square	0.99	0.94	0.92	0.91	0.92	0.93

Table S4 R-square parameter values related to exponential fits used to estimate the response time of different frequencies of V_{gs} pulses.

Frequency of V_{gs} pulses	1 Hz	5 Hz	10 Hz
R-square	0.92	0.94	0.96

Table S5 R-square parameter related to exponential fits used to estimate the response time of different V_{gs} pulse sampling times.

V_{gs} pulse sampling times	10 ms	25 ms	50 ms	100 ms	250 ms	500 ms	1 s
R-square (V_{ds}=-0.6)	0.95	0.94	0.99	0.99	1	1	1
R-square (V_{ds}=-0.8)	0.94	0.96	0.98	0.99	1	1	1

All R-square parameters are close to 1 and it shows a good fit between the exponential model and the associated decay curves.

References

1. J. Sayago, F. Soavi, Y. Sivalingam, F. Cicoira and C. Santato, *Journal of Materials Chemistry C*, 2014, **2**, 5690-5694.
2. M. Zakrewsky, K. S. Lovejoy, T. L. Kern, T. E. Miller, V. Le, A. Nagy, A. M. Goumas, R. S. Iyer, R. E. Del Sesto and A. T. Koppisch, *Proceedings of the National Academy of Sciences*, 2014, **111**, 13313-13318.
3. Y. Na and F. S. Kim, *Chemistry of Materials*, 2019, **31**, 4759-4768.