Solution-Processed Ambipolar Electrolyte-gated Field Effect Transistors from a MoS₂-polymer Hybrid for Multifunctional **Optoelectronics**

Jiaojiao Song,^{a,b} Yican Chu, ^{a,b} Zhizhen Liu^c and Haihua Xu^{a,b*}

^aDepartment of Biomedical and Engineering, School of Medicine, Shenzhen University, Shenzhen, China.

^bGuangdong Key Laboratory for Biomedical Measurements and Ultrasound Imaging, Shenzhen, China.

^cCollege of Integrative Medicine, Fujian University of Traditional Chinese Medicine,

Fuzhou, China.

KEYWORDS: Two-dimensional material, molybdenum disulfide, field-effect transistor,

flexible electronics

*Corresponding E-mail address: hhxu@szu.edu.cn

Support Information





Figure S1 The SEM image of the few-layer MoS₂ nanosheets from the solution-processed exfoliation method.

2. The EDL capacitance at the electrolyte/semiconductor interface

Impedance spectroscopy measurements were carried out to investigate the EDL capacitance of the amEGFET device by Hewlett Packard 4284A LCR meter. The source and drain electrodes were grounded while the gate electrode was connected to the anode of the LCR meter. DC voltage of 2 V and AC small signal 100 mV was applied onto the gate electrode.



Figure S2 The capacitance versus frequency at the electrolyte/semiconductor interface.



3. Dependence of the transfer characteristics on the sweep interval time

Figure S3 Dependence of the (a-c) n-type and (d-f) p-type transfer characteristics on the sweep interval time ($t_{sweep interval}$).

4. Extraction of the field-effect mobilities

To extract the p-type and n-type field-effect mobilities, the work voltages of $V_{ds} = -0.3$ V and $V_{gs} = -2.5$ V are set for hole while $V_{ds} = 0.3$ V and $V_{gs} = 4.0$ V for electron. As shown in Figure 2c of the output characteristics, both the hole and electron work conditions are both approximatively in the linear region. Therefore, both hole and electron field-effect mobilities were extracted using a linear-region mobility equation:

$$\mu = \frac{L}{W \cdot V_{ds} \cdot C_i} \times \frac{\partial I_{ds}}{\partial V_{gs}}$$
(1)

where L is the channel length, W is the channel width, V_{ds} is the drain-source voltage (V_{ds} = -0.3 V for hole and V_{ds} =0.3 V for electron, respectively), C_i is the capacitance per unit area of the EDL layer, I_{ds} is the drain-source current, V_{gs} is the applied gate voltage.

(c)₁₀ (b)₁ (a) 10 0 10 10 10 10-10-4 10-10-10-0-4 €^{10°} €¹⁰⁻⁵ €¹⁰⁻⁵ €^{10⁻⁵} 10⁻⁵ 10⁻⁶ 10-5 10-5 10-6 10-6 104 10-7 10-10-1 10-10-7 10 10-1 10-1 10-8 10-8 10-8 10 10-8 10-8 10 10-9 0.9 10-9 10⁻⁹ 10-10.9 10-9 10-6 p-type n-type -type n-type p-type n-type 10⁻¹⁰ p-type n-type 0-10 10-10 10-10 10-10 10-10 10-10 $I_{gs}^{U}(V)$ 0 I_{g1}(V) $I_{gs}^{0}(V)$ $I_{gs}^{0}(V)$ (h) (f) (g) (e) Sample 5 Sample 7 10 10 10 10-3 10 10 10 10 10-3 10-4 10 10 10 10 10 10-10 10-5 10-10-5 €¹⁰ €_104 €_104 €_104 10-6 10-6 10.6 104 10⁻⁷ 10⁻⁸ 10-7 10⁻⁷ 10⁻⁸ 1.0 10⁻⁷ 10⁻⁸ 107 10 1.01 10-8 10-8 10-8 10-5 10-4 10-9 10-9 10-9 10⁻⁹ 10-9 10 10-5 p-type 10-6 n-typ p-type n-type p-type n-typ p-type n-type 10⁻¹⁰ 10-10 10-10 10-1 10-3 0 I_{gs}(V) 0 I_{g1}(V) 1_{g1}(V) 0 I_{g1}(V) (I) (j) (k) 10 (i) nple10 nple11 Sa Sa Sa mple12 1.01 10 10 10 10-3 10 10 1.01 10-4 10 10 10 10 10 10-5 €^{10⁵} 10 €¹⁰⁴ ∎104 10 10 €_____104 10-6 10-10-6 10⁻⁷ 10⁻⁸ 10-10. 10 10 10-2 10-8 10-4 10⁻⁸ 10⁻⁹ 10-8 10-8 10-5 10-4 10-9 10⁻⁹ 10-9 10-9 10-4 10-9 10-6 p-type n-type p-type n-type 10⁻¹⁰ **p-type** 10⁻¹⁰ **p-type** n-type 10-1 10 0 I_{g1}(V) 0 I_{g1}(V) 0 I_{g1}(V) 0 I_{g1}(V) (n) 10 (p) (o) 10⁻ (m) nple13 Sample14 Sample16 Sai mple15 10 10 10-3 10-3 10 10 0-3 10 10 10-3 10-4 10-4 10-4 10 10 10 10 10 €¹⁰⁻⁵ 10-4 10-5 10⁻⁵ 10-3 10-5 € _#^{10*} 10⁴ (2) 10⁴ 10° € 10° 10-6 104 10-1.0-7 1.0 10-7 10 10-7 107 1.0" 10-8 10-8 10-4 10-8 10-4 10-4 10-8 10-4 10-9 10-9 10-6 0-5 10 10-5 10-6 n-type p-typ p-type p-type n-typ n-type -type n-type 10-10 10-1 10-1 0 I_m(V) $\stackrel{0}{I_{gs}(V)}$ I_{gs}(V) 0 I_{gs} (V)

5. Transfer characteristics of all 16 amEGFET samples

Figure S4 The transfer characteristics of the all 16 amEGFET devices measured at room temperature in air.

6. The extract of the time constants of the rising and falling processes

The exponential relationships of $V_{op} \propto (1 - e^{1 - \frac{t}{\tau_r}})$ and $V_{op} \propto e^{-\frac{t}{\tau_f}}$ were used to fit the rising and falling modulation response under different high levels of electrical input (V_{HI}), respectively, where V_{op} is the optical output, τ_r is the time constant of the rising period and τ_f is the time constant of the falling period. The fitting results can be seen in Figure S5, where the blue and orange lines are the experimental and calculated data for optical output.



Figure S5 Dependence of the time constant τ_r in a rising period and τ_f in a falling period on the high level of an electrical input (V_{HI}).