Supporting information

# Low-Power Consumption Light-stimulated Synaptic transistors Based on Natural Carotene and Organic Semiconductors

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## Experimental section

*Materials and Devices Fabrication*

We purchased PDPP4T (Poly[2,5-bis(2octyldodecyl)pyrrolo[3,4-c]pyrrole-1,4(2H,5H)-dione-3,6-diyl)-alt(2,2′;5′,2″;5″,2‴-quaterthiophen-5,5‴-diyl)]) with no further purification from Ossila Co., Ltd. . Carotene was bought on Tokyo chemical industry Inc. without further purification. Heavily n-doped Si wafers with thermally grown 300 nm $SiO_2$ layer was utilized as both substrate and gate electrodes. Before fabrication process, the substrate was first sonicated in acetone and isopropanol for 30 min, and later washed with ethanol and water alternately. At last, the substrate was dried by $N_2$ flow. Afterwards, the $Si/SiO_2$ substrate was treated by dodecyltrichlorosilane (OTS) solution. To fabricate the LSSTs, at 3000 rpm for 60 s, the carotene/PDPP4T solution (0.2 mg carotene and 5 mg PDPP4T blended and dissolved in 1 mL $CHCl_3$) was spin-coated on the substrate. Next, to protect the carotene from thermal decomposition, the carotene/PDPP4T film was set in a glove box at room temperature for 5 h. The LSSTs films of varied material weight ratios were prepared on the $Si/SiO_2$ wafer. Afterwards, by thermal evaporation, patterned Au electrodes of 40 nm were deposited on the films surfaces. For pure PDPP4T devices, the PDPP4T solution (5 mg/mL in $CHCl_3$) was formed on the substrate by spin-coating.

*Characterization*

Atomic force microscope was carrid out to study the thickness and morphologies of the OFETs films (SEIKO SPA300HV). Electrical properties were obtained by Keithely 4200 characterization system. Using an ultraviolet and visible spectrophotometer (Agilent Cary 5000), UV-Vis absorption spectra were observed. In order to characterize optical properties of the devices, we used a xenon lamp for monochromatic light of different wavelengths (Omno 330150, Beijing NBeT). By electronic timer (GCI-73, Daheng Science and Technology), the transient light response behavior of the devices was measured.

Figure S1. Weight ratio dependent photoresponsivity (R) of our devices. The label A, B, C, and D represent weight ratios of “5:1”, “5:0.5”, “5:0.2”, and “5:0.1”, respectively. Error bars represent standard errors from five independent tests.

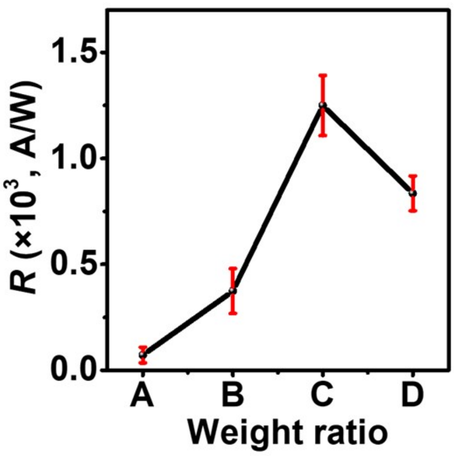


Figure S2. AFM image of the natural carotene/PDPP4T film.

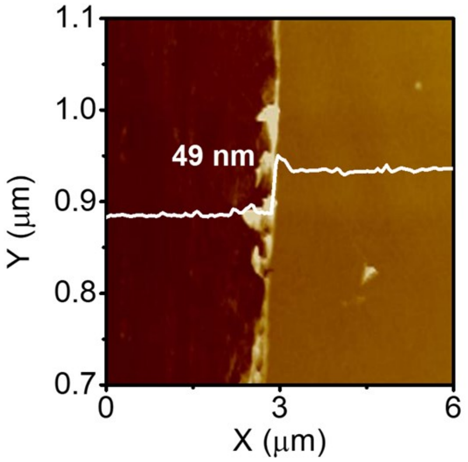



Figure S3. Steady-state photoluminescence characterization.

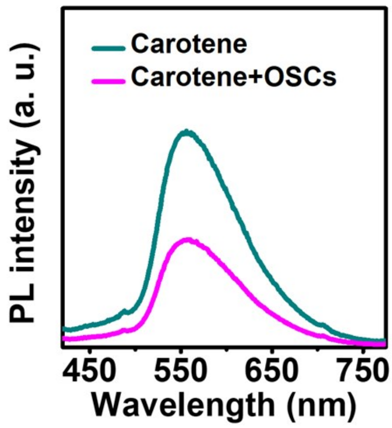
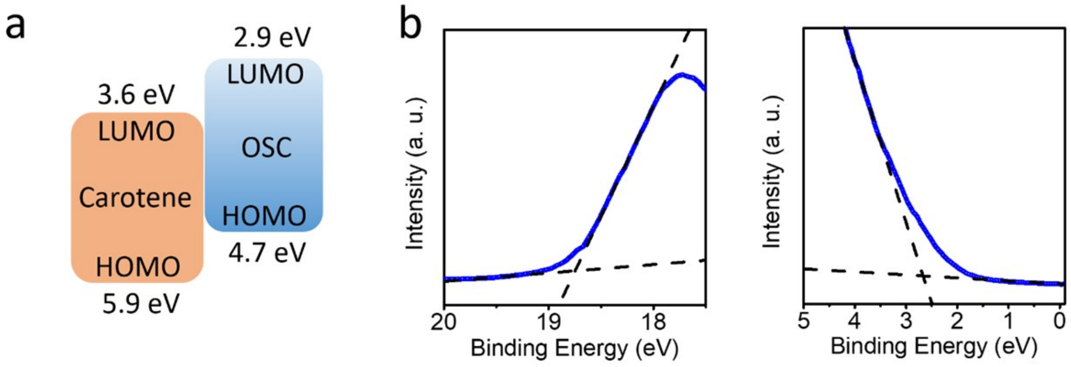


Figure S4. (a) Energy band diagram of the natural carotene and PDPP4T. (b) The energy level structure of carotene calculated by ultraviolet photoelectron spectroscopy (UPS) measurements.




**HOMO = 22.2-18.8+2.5 = 5.9 eV**

**LUMO = 5.9-2.3 = 3.6 eV**

Figure S5. (a) Transfer curves of the LSSTs device. (b) The stability of the hybrid device tested under dark condition.

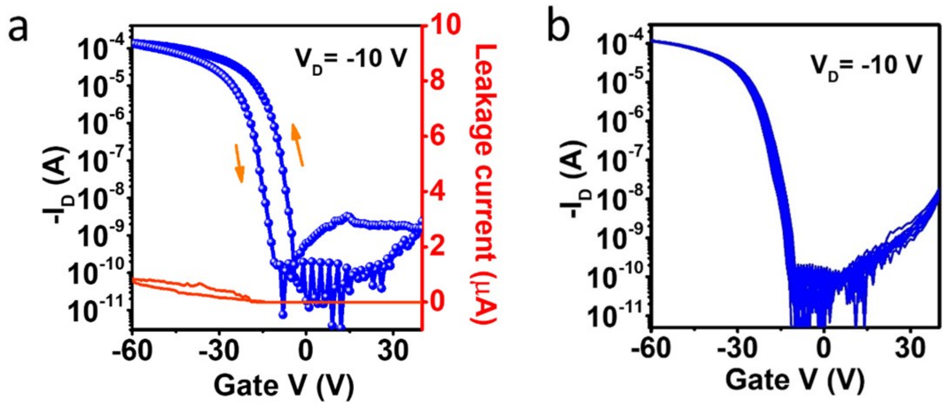



Figure S6. Photoresponse performance of the PDPP4T OFETs.

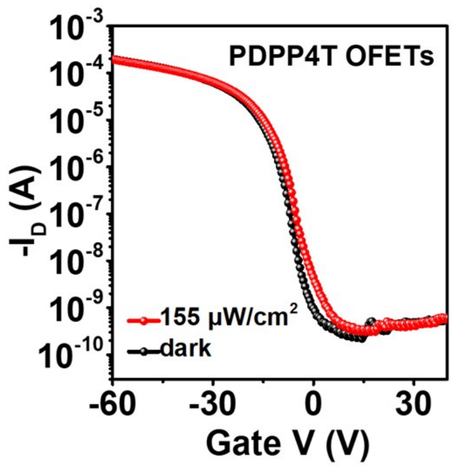


Figure S7. $I_{photo}/I_{dark}$ ratio of the LSSTs as a function of light intensity.

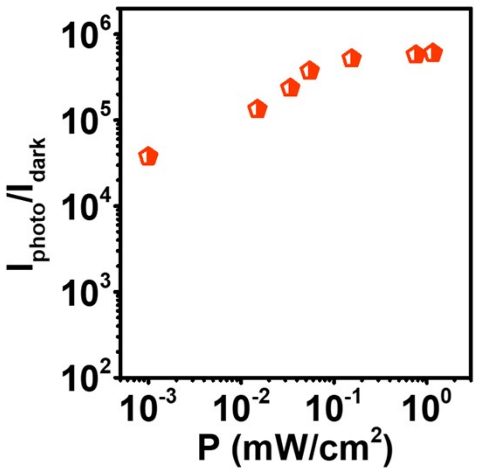



Figure S8. The memory level of the LSSTs as a function of presynaptic spike intensity.

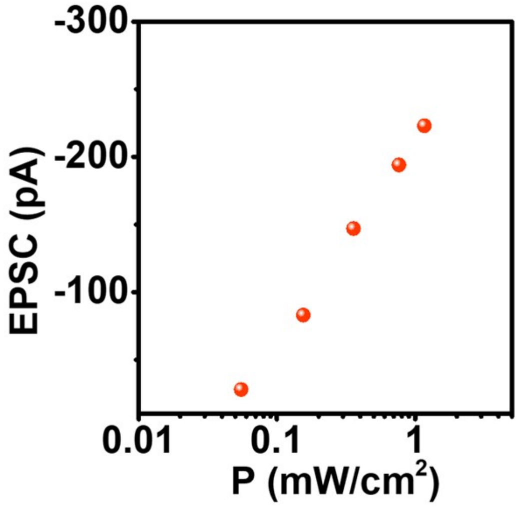


Figure S9. PPF index of the LSSTs defined as $(A_2\text{-}A_1)/A_1\times100\%$.

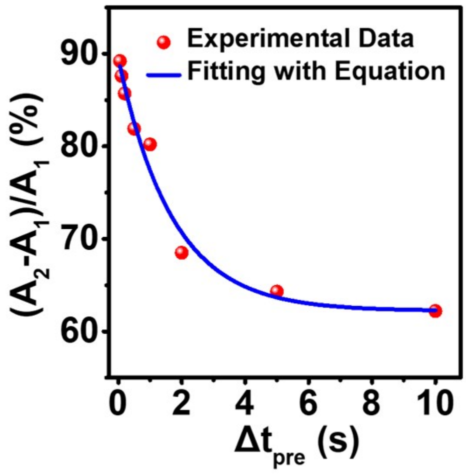



Figure S10. Long-term stability of the LSSTs. a) EPSC behavior of the LSSTs in 7 days. b) EPSC behavior of the LSSTs in 60 days.

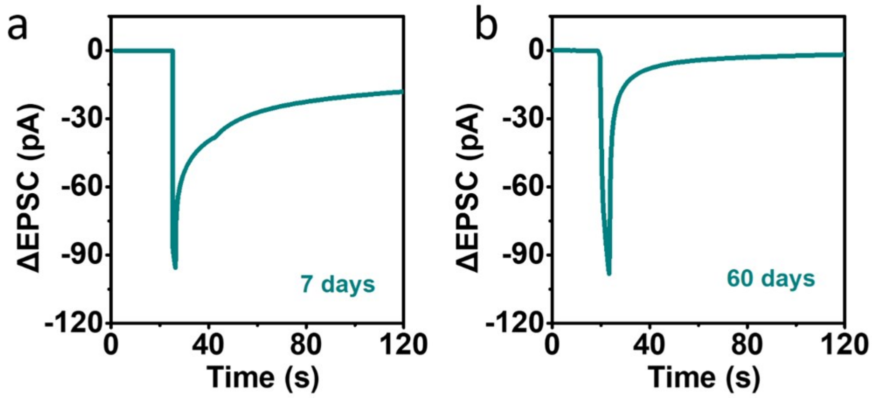



Figure S11. Optical writing and gate bias erasing properties of the device.

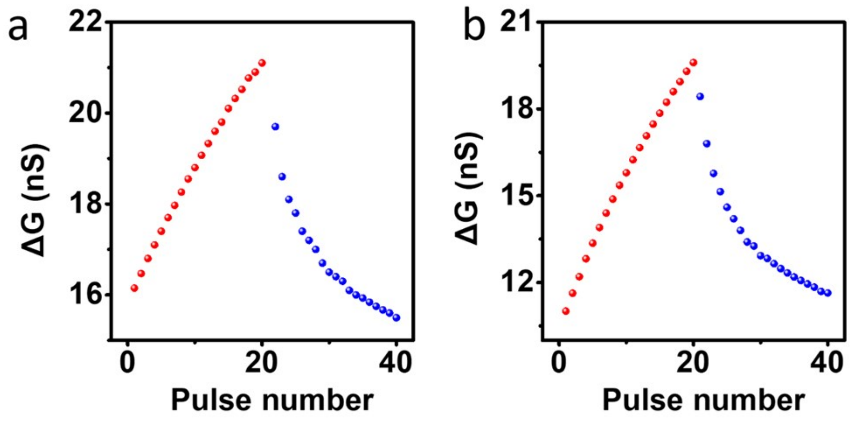


Table S1. Comparison of power consumption between our LSSTs and reported organic synaptic devices.

| Device Structure | Wavelength | Operation Voltage | Power Consumption | Refs. |
|---|---|---|---|---|
| Ion-gel/P3HT | 550 nm | -1.2 V | 510 pJ | [1] |
| $MoS_2$/PTCDA | N/A[a] | $2.5\times10^{-3}$ V | 10 pJ | [2] |
| NT-CN/PMMA/pentacene | 440 nm | -0.3 V | 18 fJ | [3] |
| Pentacene/PMMA/$MoSe_2$/Bi2$Se_3$ | 790 nm | -10 V | 0.75 nJ | [4] |
| Organic nanowire | N/A | -0.001 V | 13 fJ | [5] |
| DPPDTT/$CsPbBr_3$ | 450 nm | -0.0005 V | 0.5 fJ | [6] |
| Chlorophyll/PDPP4T | 430 nm | $-10^{-5}$ V | 0.25 fJ | [7] |
| P3HT nanowire | N/A | 0.75 V | 1.23 fJ | [8] |
| **Natural carotene/OSCs** | **450 nm** | **$-10^{-5}$ V** | **0.0034 fJ** | **This work** |

[a] Not applicable

**Reference**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