

Supporting Information

Intrinsically stretchable all-polymer neuromorphic visual adaptive transistors based on
multidimensional-phase-separation-induced micromesh

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Supplementary Methods

Surface energy measurements

The surface energy of elastomer films, conjugated polymer films and all the hybrid films were calculated according to the Owens-Wendt method¹:

$$\gamma_s = \gamma_s^p + \gamma_s^d \quad (1)$$

$$(1 + \cos \theta_l) \gamma_l = 2 \left(\sqrt{\gamma_l^d \gamma_s^d} + \sqrt{\gamma_l^p \gamma_s^p} \right) \quad (2)$$

where γ_s , γ_s^p and γ_s^d were the total surface energy, polar component and dispersive component of surface energy, respectively. The total surface energy (γ_l), dispersion component (γ_l^d) and polar component (γ_l^p) were 50.8 mJ m⁻², 50.42 mJ m⁻² and 0.38 mJ m⁻² for diiodomethane, and 72.8 mJ m⁻², 29.1 mJ m⁻² and 43.7 mJ m⁻² for water, respectively.

Works of adhesion measurements

The works of adhesion between different hybrid photosensitive films and nanoconfined semiconductor films were calculated as followed ^[2]:

$$W_{Sl/S2} = 2 \left(\sqrt{\gamma_{Sl}^d \gamma_{S2}^d} + \sqrt{\gamma_{Sl}^p \gamma_{S2}^p} \right) \quad (3)$$

where W , γ^d and γ^p were the calculated works of adhesion, polar component and dispersive component of measured surface energy, respectively.

Defect state density measurements

The defect-tunability of the MPSM films were certified according to hole-only device measurements and calculated as followed:

$$V_{TFL} = \frac{eN_t L^2}{2\epsilon\epsilon_0} \quad (4)$$

where e was the elementary charge, L was the thickness of the semiconductor film, ϵ_0 was the vacuum dielectric constant, and ϵ was the relative dielectric constant ^[3].

Electronic properties measurements

The mobility (μ) and threshold voltage (V_{th}) were important parameters for evaluating the electronic performances of OFETs. These values could be extracted from the curve of the drain current (I_{DS}) versus the gate voltage (V_G). In the saturation regime, the drain current (I_{DS}) versus the gate voltage (V_G) according to the following equation ^[4]:

$$I_{DS} = \frac{W}{2L} C_i \mu_{sat} (V_G - V_{th})^2 \quad (5)$$

where W and L represented the channel length and width, respectively. C_i was the capacitance of the gate dielectric.

The mobility was calculated by the slop of $\sqrt{|I_{DS}|}$ versus V_G according to the following equation ^[5]:

$$\mu_{sat} = \left(\frac{\partial \sqrt{|I_{DS}|}}{\partial V_G} \right)^2 \frac{2L}{WC_i} \quad (6)$$

$$|V_G - V_{th}| < |V_{DS}| \quad (7)$$

The V_{th} of the device was obtained by extrapolating a plot of $\sqrt{|I_{DS}|}$ versus V_G to $I_{DS} = 0$.

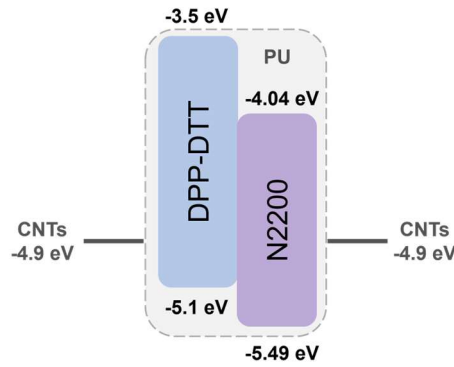
Consumption calculation of synaptic behavior

The energy consumption (E) of typical synaptic behaviors could be calculated as follows [6]:

$$E = I_{peak} \times t \times V \quad (8)$$

where I_{peak} , t , and V were the peak value of EPSC, light pulse width, and operating voltage, respectively.

1 **Supplementary Figures**



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3 **Supplementary Figure 1.** Simplified energy level diagram of DPP-DDT/N2200/PU based MPSM
4 heterojunctions.

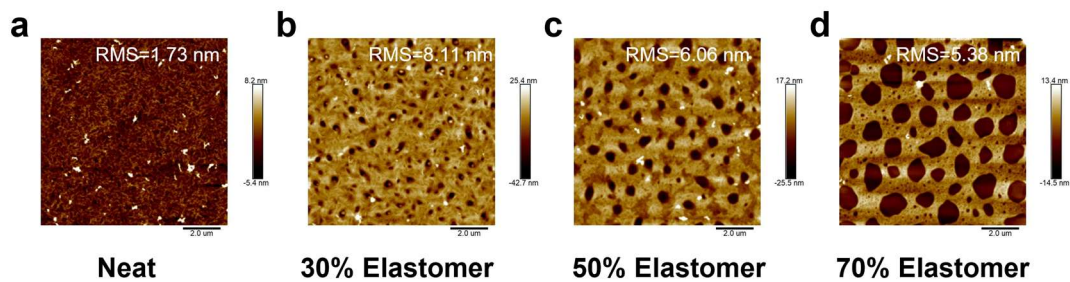
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6 **Supplementary Table 1.** Surface energy of multiple semiconductor, elastomer and heterojunction
7 films. Notably, the default hybrid weight ratio of DPP-DDT and N2200 was 1:1.

Materials		Contact angle (°)		Surface energy (mJ m ⁻²)		
		DI water	DIM	γ^p	γ^d	γ^s
DPP-DDT		97.1	51.9	0.49	33.20	33.69
N2200		100.5	55.4	0.26	31.24	31.5
DPP-DDT/N2200		105.7	55.7	0.43	32.57	33.01
PU		78.3	21.3	1.24	46.23	47.48
SEBS		103.0	56.0	0.10	30.90	31.00
DPP-DDT/N2200 :PU	3:7	101.6	61.8	0.01	27.43	27.44
	5:5	102.5	61.3	0.01	28.91	28.92
	7:3	105.0	60.0	0.09	28.95	29.03

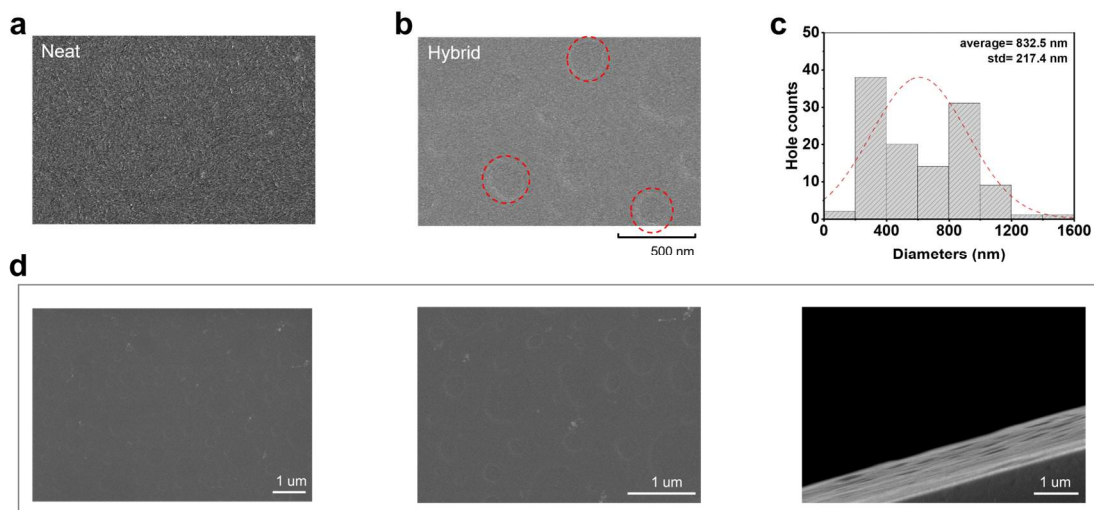
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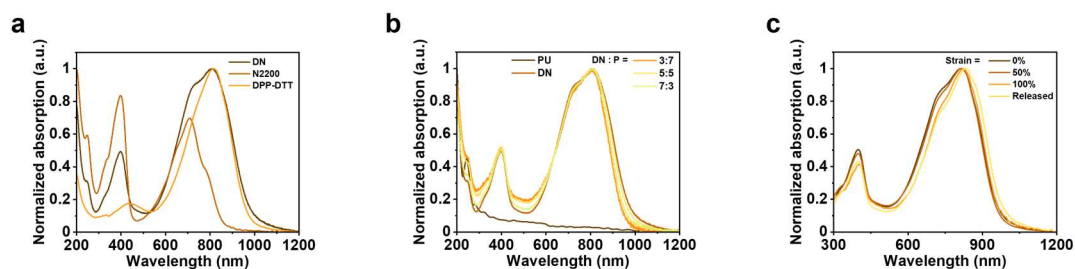


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11 **Supplementary Figure 2.** Atomic force microscope (AFM) images of the hybrid photosensitive
12 heterojunction film morphologies with different hybrid elastomer ratios. **a.** Neat DPP-DDT/N2200
13 heterojunction films. **b.** DPP-DDT/N2200/PU heterojunction films with a hybrid weight ratio that
14 DPP-DDT/N2200: PU= 7:3. **c.** DPP-DDT/N2200: PU= 5:5. **d.** DPP-DDT/N2200: PU= 3:7. The
15 transforming states showed that the introduction of elastomer could promote phase separation to
16 form micromesh morphologies. Moreover, as the elastomer content increased, the hole area of film
17 morphologies could undergo an evolution process of becoming larger with gradually decreased
18 surface roughness.



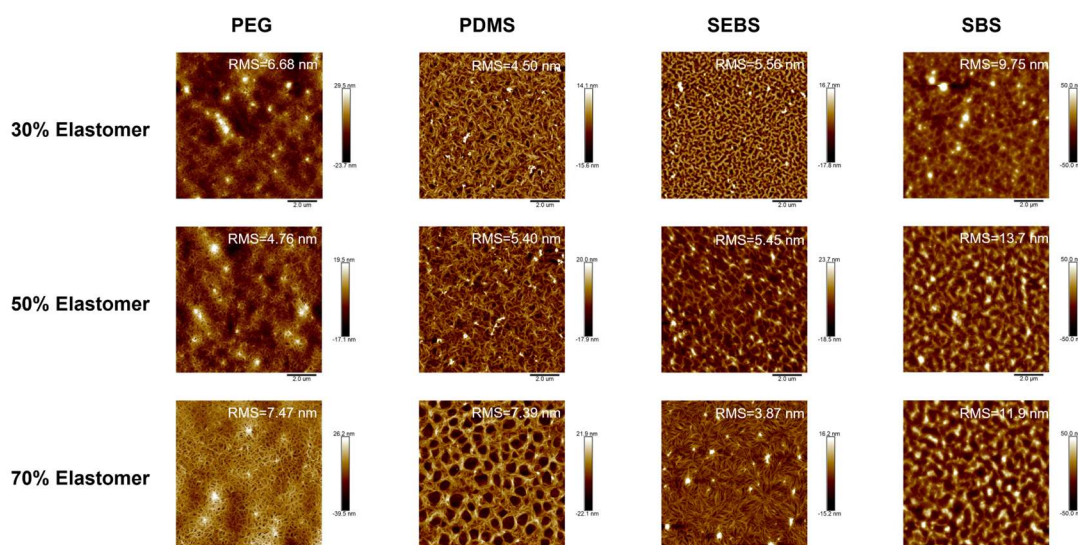
Supplementary Figure 3. Scanning electron microscope (SEM) images of different photosensitive heterojunction films with different morphologies. **a.** Neat DPP-DDT/N2200 heterojunction films. **b.** Hybrid DPP-DDT/N2200/PU heterojunction films. There was an obvious transformation as the neat film exhibited flat morphology and the hybrid film display micromesh morphology. **c.** Hole statistics under 10μm×10μm area with 70%-PU hybrid films. **d.** Surface and cross-section SEM images for hybrid films. It showed the hole statistics under the range area, in which the average pore size was about 832 nm, and the standard deviation was 217 nm. Therefore, the coefficient of variation ($CV = \text{std}/\text{average} \times 100\%$) was obtained as 0.261 which could be regarded as moderate uniformity. Although there were some small holes (< 400 nm), the surface morphology was occupied by large holes (> 400 nm) as a whole, and a lower variation trend would ensure excellent device performance.



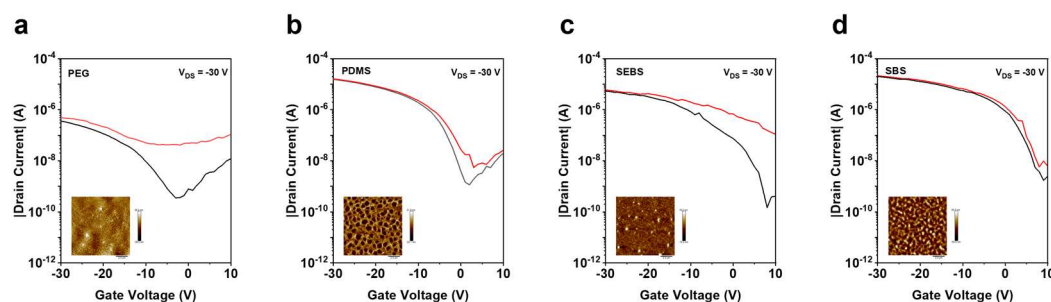
Supplementary Figure 4. Normalized UV-vis absorption spectra of different photosensitive heterojunctions and elastomer. **a.** Neat polymers and heterojunctions without elastomer. **b.** Different photosensitive heterojunctions with elastomer. **c.** MPSM photosensitive heterojunctions under different strains. ("DN" referred to the hybrid polymer semiconductors of DPP-DDT and N2200, and "P" referred to the elastomer PU)

Supplementary Table 2. Surface energy of multiple elastomers.

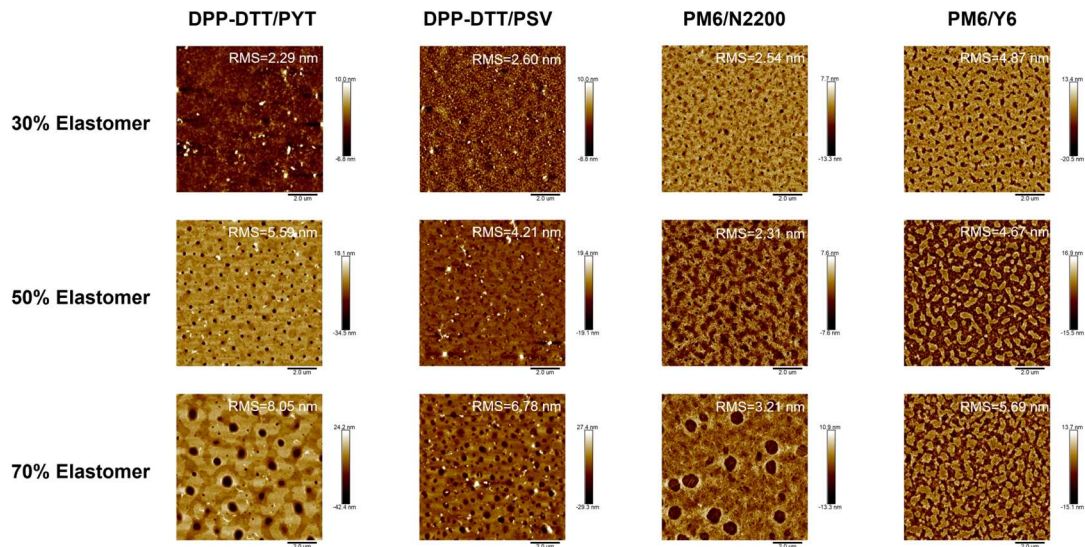
Materials	Contact angle (°)		Surface energy (mJ m^{-2})		
	DI water	DIM	γ^p	γ^d	γ^s
PEG	77.5	19	1.20	47.12	48.32
PU	78.3	21.3	1.24	46.23	47.48
SBS	105.1	54.6	0.31	32.46	32.77
SEBS	103.0	56.0	0.10	30.90	31.00
PDMS	106.0	60.2	0.16	29.05	29.21



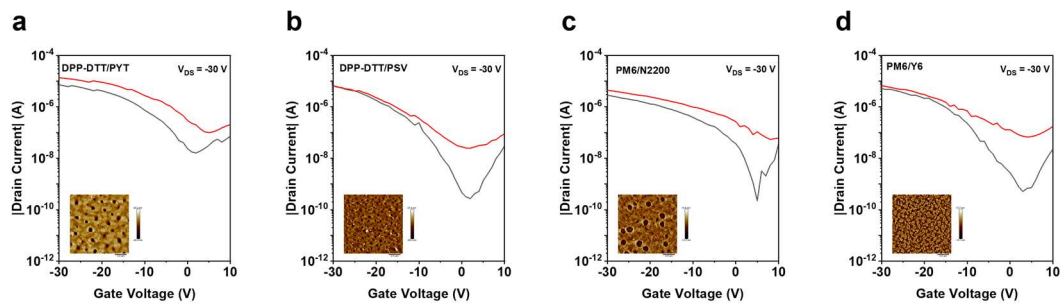
Supplementary Figure 5. AFM images of different DPP-DTT/N2200 heterojunction photosensitive films hybridized with PEG, PDMS, SEBS, and SBS, respectively, at different elastomer contents ranging from 30 to 70 %.



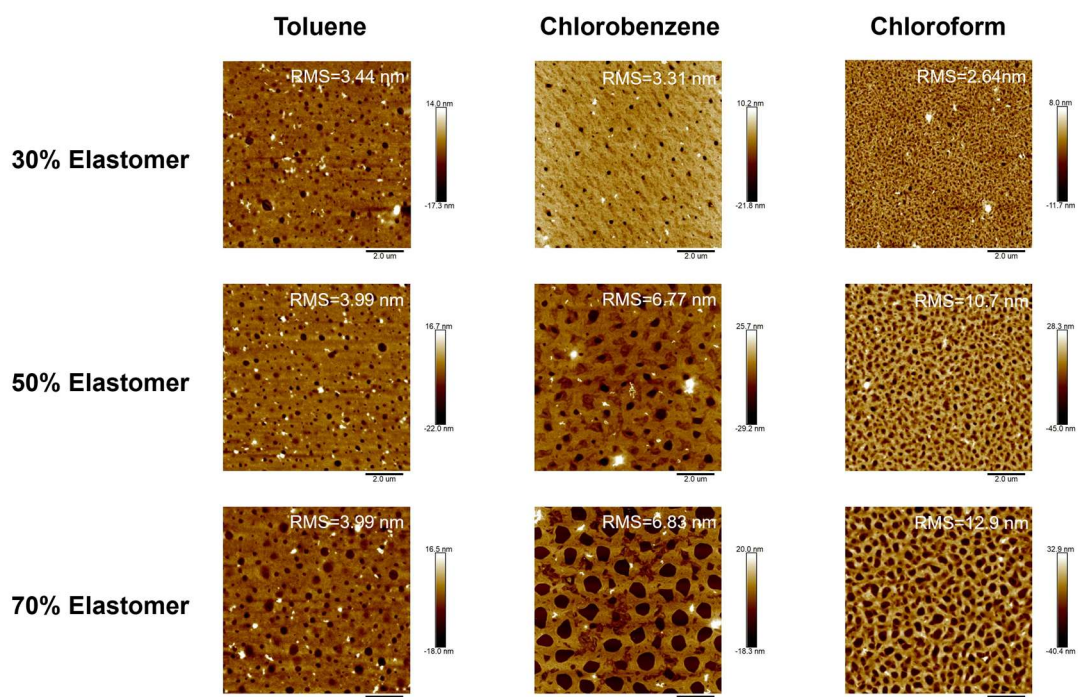
Supplementary Figure 6. Typical transfer curves ($L/W = 2800 \mu\text{m}/50 \mu\text{m}$) of different DPP-DTT/N2200 photosensitive heterojunction films hybridized with a. PEG, b. PDMS, c. SEBS, and d. SBS, respectively, at a fixed content of 70% (808 nm, $P_{\text{in}} = 1050.14 \mu\text{W cm}^{-2}$).



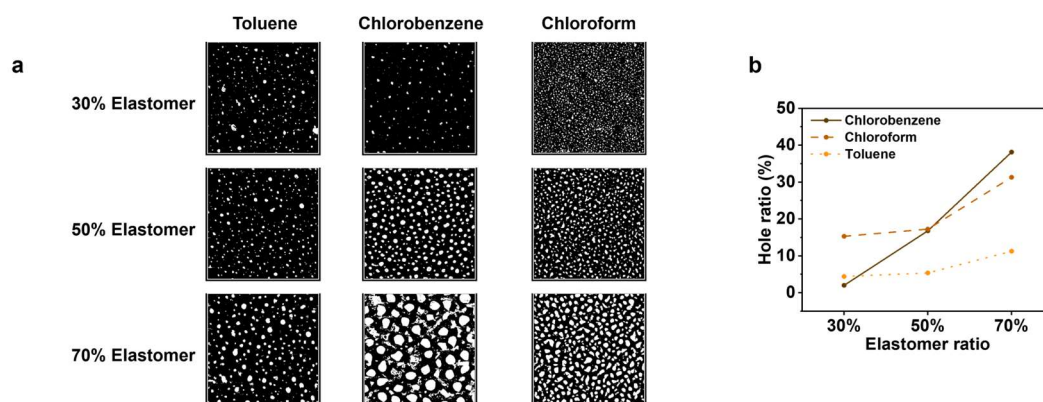
Supplementary Figure 7. AFM images of different PU-based photosensitive heterojunction films hybridized with DPP-DDT/PYT, DPP-DDT/PSV, PM6/N2200, PM6/Y6, respectively, at different elastomer contents ranging from 30 to 70%.



Supplementary Figure 8. Typical transfer curves ($L/W = 2800 \mu\text{m}/50 \mu\text{m}$) of different PU-based photosensitive heterojunction films hybridized with **a.** DPP-DDT/PYT, **b.** DPP-DDT/PSV, **c.** PM6/N2200, **d.** PM6/Y6, respectively, at a fixed content of 70% (808 nm, $P_{\text{in}} = 1050.14 \mu\text{W cm}^{-2}$).



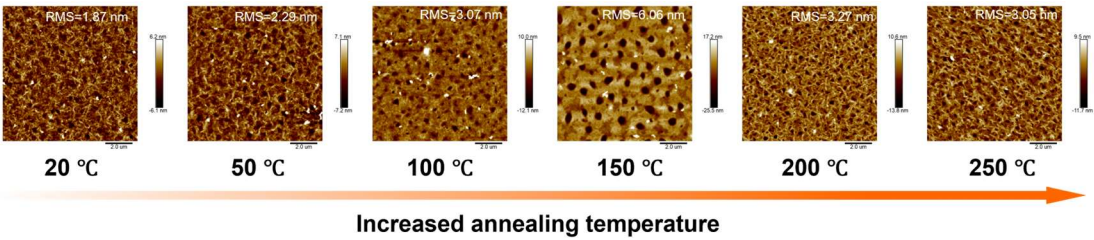
Supplementary Figure 9. AFM images of MPSM photosensitive heterojunction films that dissolved in different solvents, such as toluene, chlorobenzene, and chloroform, respectively, at different elastomer contents ranging from 30 to 70 %.



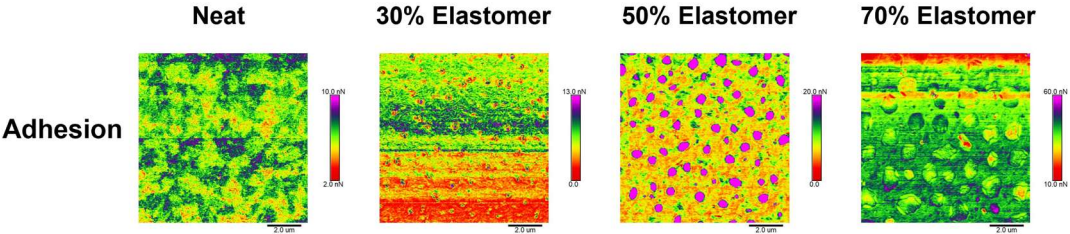
Supplementary Figure 10. Hole ratio calculation of MPSM photosensitive heterojunction films that dissolved in different solvents at different elastomer contents ranging from 30 to 70%, where Hole ratio = Hole area/Total area. **a.** High-contrast image output with Image J. **b.** Curves of hole ratio with different solvents

Supplementary Table 3. Hole ratio calculation of MPSM photosensitive heterojunction films that dissolved in different solvents, at different elastomer contents ranging from 30 to 70 %.

Materials	Solvent	Ratio	Hole ratio
DPP-DDT/N2200/PU	Chlorobenzene	3:7	38.12
		5:5	16.79
		7:3	2.00
	Chloroform	3:7	31.30
		5:5	17.24
		7:3	15.30
	Toluene	3:7	11.25
		5:5	5.37
		7:3	4.40



Supplementary Figure 11. AFM images of MPSM photosensitive heterojunction films with various annealing temperature from 20 °C to 250 °C.

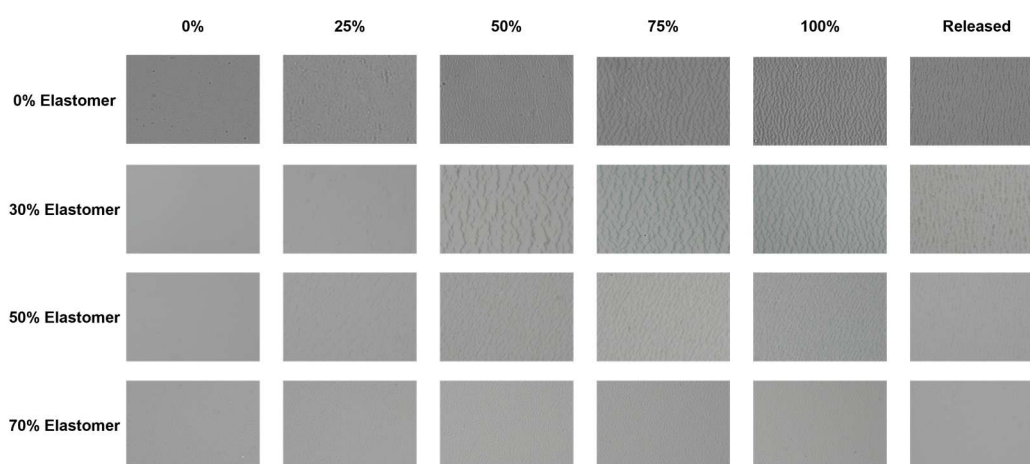


Supplementary Figure 12. Peak-force quantitation nanomechanical mapping (PFQNM) of different MPSM photosensitive heterojunction films, at different elastomer contents ranging from 0 to 70 %. It demonstrated obvious upward trends of adhesion.

Supplementary Table 4. Surface energy and works of adhesion between different photosensitive heterojunction films layer and SEBS dielectric layer. The introduced elastomer provided closer surface energy and stable work of adhesion for the ideal interfacial.

Materials		Surface energy (mJ m ⁻²)			Work of adhesion (mJ m ⁻²)
		γ^p	γ^d	γ^s	$W_{sl/s2}$
DPP-DTT		0.49	33.20	33.69	64.50
N2200		0.26	31.24	31.5	62.46
DPP-DTT/N2200		0.43	32.57	33.01	63.86
DPP-DTT/N2200:PU	3:7	0.01	27.43	27.44	58.29
	5:5	0.01	28.91	28.92	59.84
	7:3	0.09	28.95	29.03	60.01
SEBS (dielectric)		0.10	30.90	31.00	

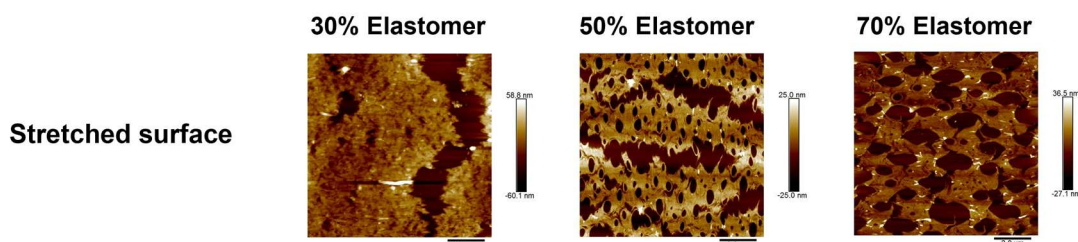
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5 **Supplementary Figure 13.** Optical microscope images of the hybrid photosensitive heterojunction
6 film morphologies with different hybrid elastomer ratios under evolved strain from 0% to 100%
7 and released state. When applied stretching strain, it demonstrated obvious cracks in neat
8 heterojunction films, minor cracks in low-elastomer-content films and almost no cracks in the films
9 with 70% elastomer, since the elastomer PU effectively increased the viscoelasticity and
10 stretchability of the heterojunctions.

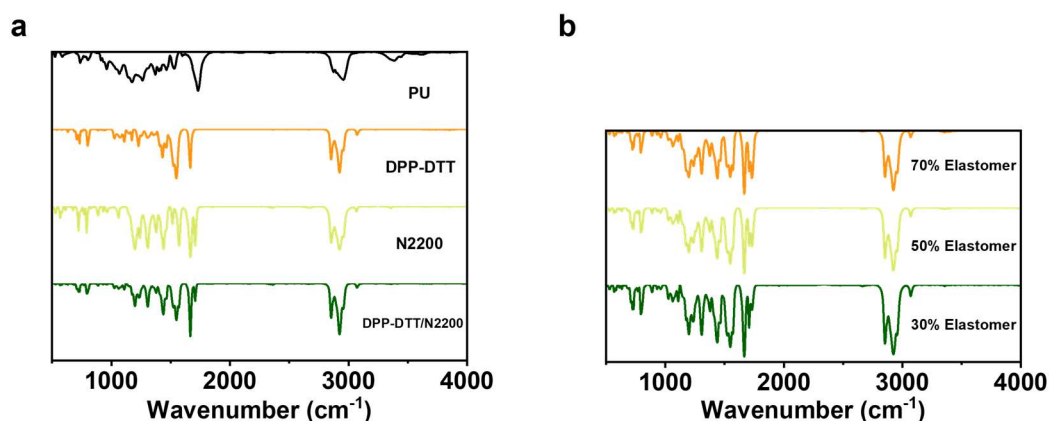
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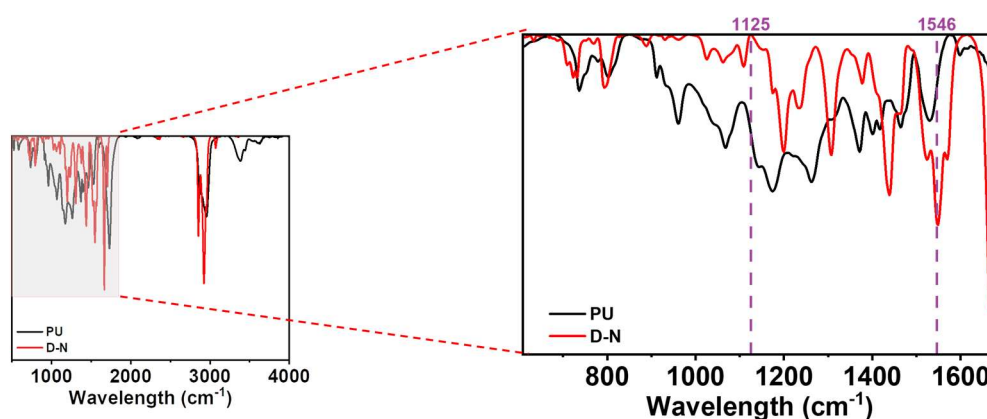
Supplementary Figure 14. AFM images of stretched MPSM photosensitive heterojunction films
surface, at different elastomer contents ranging from 30 to 70 %. The stretched films were obtained
by thermal lamination-transfer and pre-stretched procedures, that crosslinked PDMS substrate was
first used to transfer the pristine films from the OTS-treated Si-wafer, and the conducted the second
transfer to the clean Si-wafer surface when kept a pre-stretched 50% strain.

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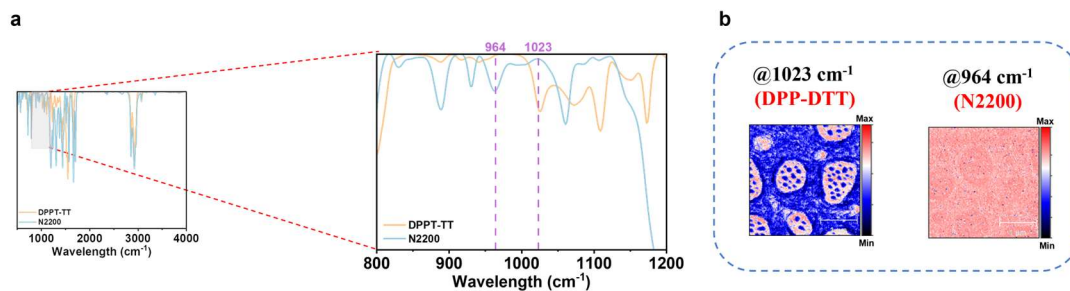
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Supplementary Figure 15. The Fourier transform infrared (FTIR) spectrometer curves of different films. **a.** Comparison of elastomer, polymer semiconductor and neat photosensitive heterojunction. **b.** Comparison of MPSM photosensitive heterojunction with different elastomer contents of 30%, 50% and 70%.

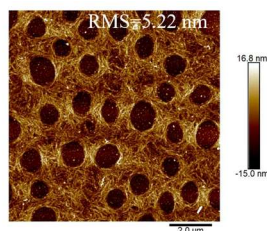


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Supplementary Figure 16. The Fourier transform infrared (FTIR) spectrometer curves between elastomer and neat photosensitive heterojunction. Based on the peak intensity contrast, the 1125 cm^{-1} wavelength was picked for PU differentiation and the 1546 cm^{-1} wavelength was for DPP-DTT/N2200 photosensitive heterojunction.

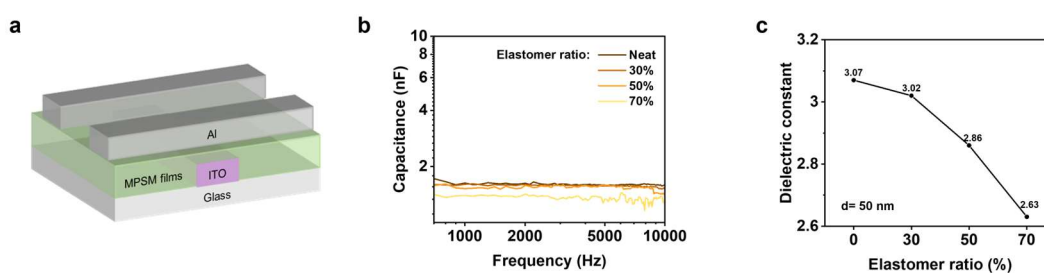


Supplementary Figure 17. a. FTIR spectrometer curves between different polymer semiconductors. Based on the peak intensity contrast, the 946 cm⁻¹ wavelength was picked for N2200 differentiation, and the 1023 cm⁻¹ wavelength was for DPP-DTT. **b.** The scanning near-field optical microscopy (SNOM) images of washed MPSM films at the 946 cm⁻¹ and 1023 cm⁻¹ wavelength.

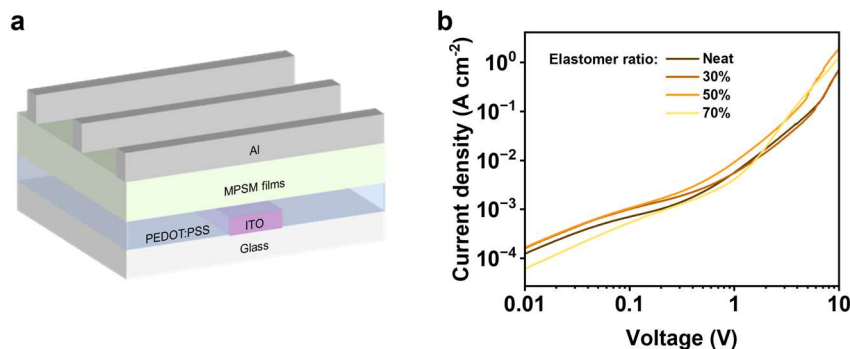


washed surface

Supplementary Figure 18. AFM images of washed MPSM photosensitive heterojunction film surface, where the elastomer was washed off by solvent.



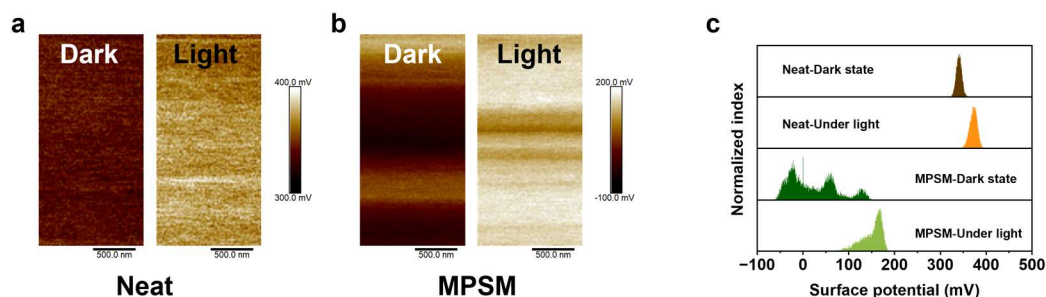
Supplementary Figure 19. The series capacitance measurements of photosensitive heterojunctions with different elastomer ratio. **a.** Device structure schematic for the capacitance measurements. **b.** The capacitance measurement curves. The capacitance at the frequency of 1000 Hz was used for further calculation. **c.** The curves of calculated dielectric constant with different elastomer ratio.



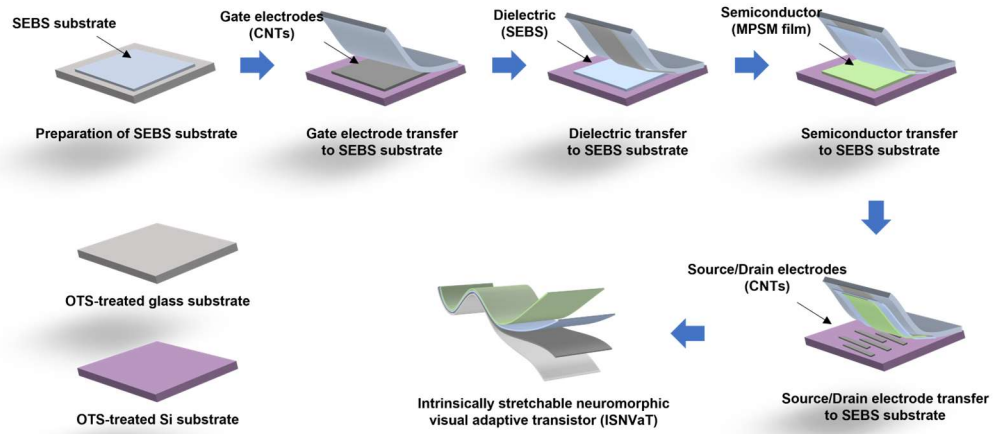
Supplementary Figure 20. The hole-only devices measurements based on photosensitive heterojunctions with different elastomer ratio. **a.** Device structure schematic for the hole-only devices measurements. **b.** SCLC curves of different MPSM photosensitive heterojunction films.

Supplementary Table 5. The V_{TFL} and N_t among various MPSM photosensitive heterojunction films.

Elastomer ratio	V_{TFL} (V)	N_t (cm ⁻³)
Neat	0.444	6.026×10^{16}
30%	0.474	6.329×10^{16}
50%	0.541	6.841×10^{16}
70%	1.089	12.66×10^{16}

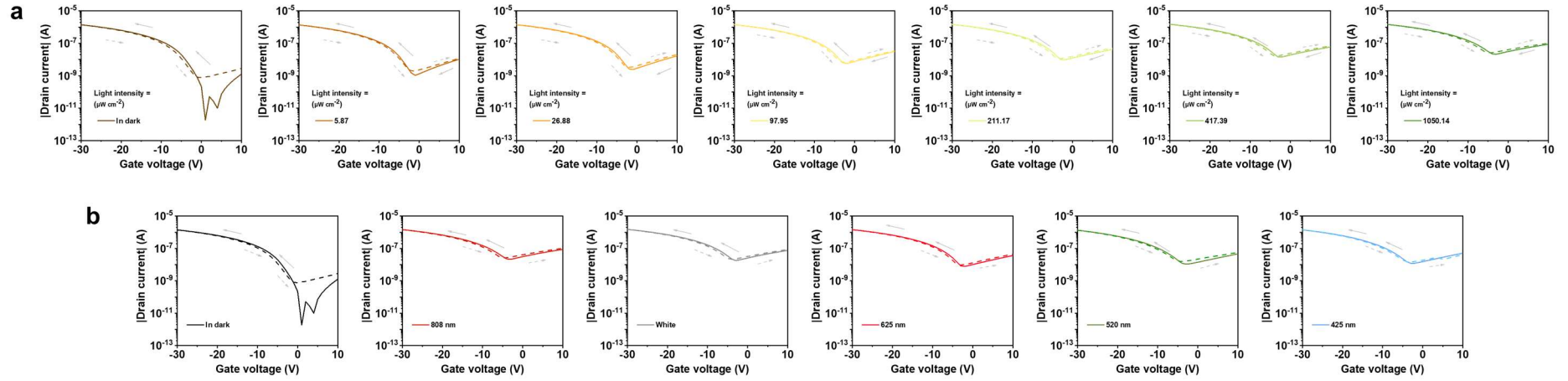


Supplementary Figure 21. Comparison between neat and MPSM heterojunction in surface potential. **a.** Surface potential images films under dark state and illumination (808 nm, 1050.14 $\mu\text{W cm}^{-2}$) of neat heterojunction films, and **b.** MPSM heterojunction films. **c.** The corresponding surface potential profiles.



Supplementary Figure 22. Schematic illustration of the fabrication process diagram for the intrinsically stretchable neuromorphic visual adaptive transistors (ISNVaTs). The device (channel length/width = 200 μm / 4000 μm) in a bottom-gate-top contact configuration was constructed through sequential thermal lamination-transfer process.

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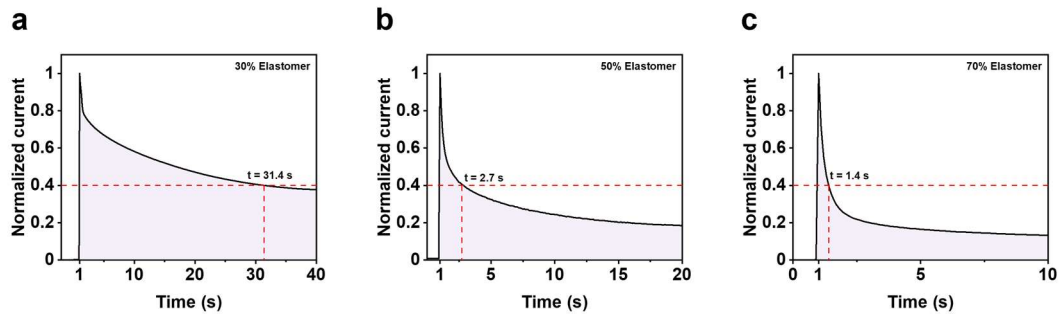


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4 **Supplementary Figure 23.** Independent typical transfer curves with hysteresis of the ISNVaTs under different conditions: **a.** 808 nm illumination with various
 5 intensities. **b.** various wavelengths ($P_{in} = 1050 \mu\text{W cm}^{-2}$).

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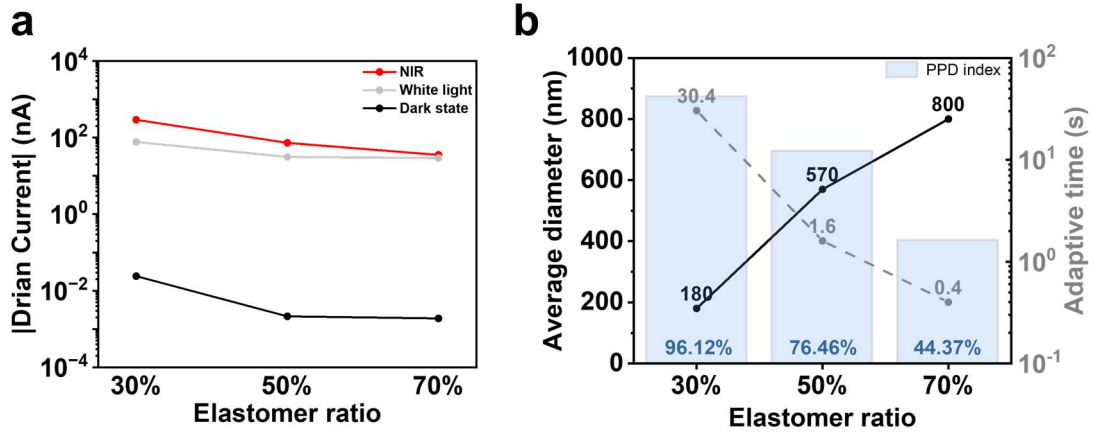
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Supplementary Figure 24. The effect of elastomer content on adaptive behaviors. Maximum photocurrents were all located at $t = 1$ s. **a.** 30% Elastomer. **b.** 50% Elastomer. **c.** 70% Elastomer. ($V_{DS} = -60$ V, $V_G = 0$ V, 808 nm, $1050.14 \mu\text{W cm}^{-2}$)



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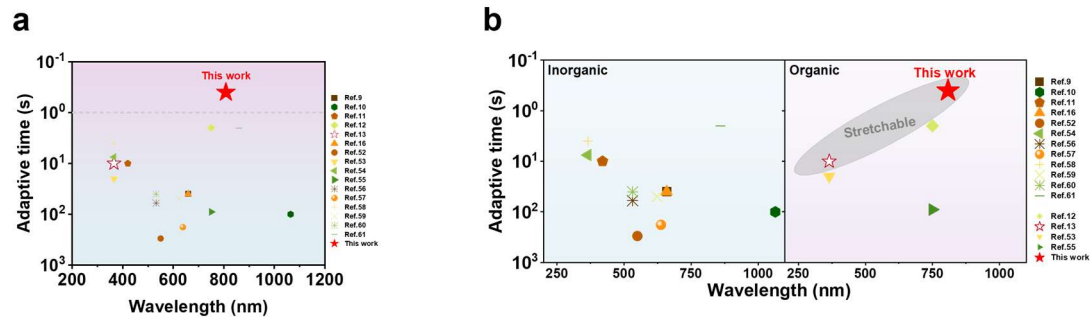
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Supplementary Figure 25. a. Photosensitivity under different elastomer ratio. **b.** Average hole diameter, adaptive time and PPD index under different elastomer ratios. (The average diameter was the statistics of 30 holes represented by $10 \mu\text{m} \times 10 \mu\text{m}$ AFM figures, while the adaptive time and PPD index were obtained by the best performance at specific ratio).



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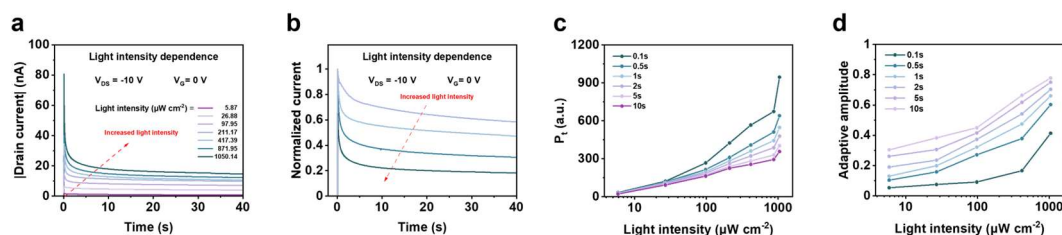
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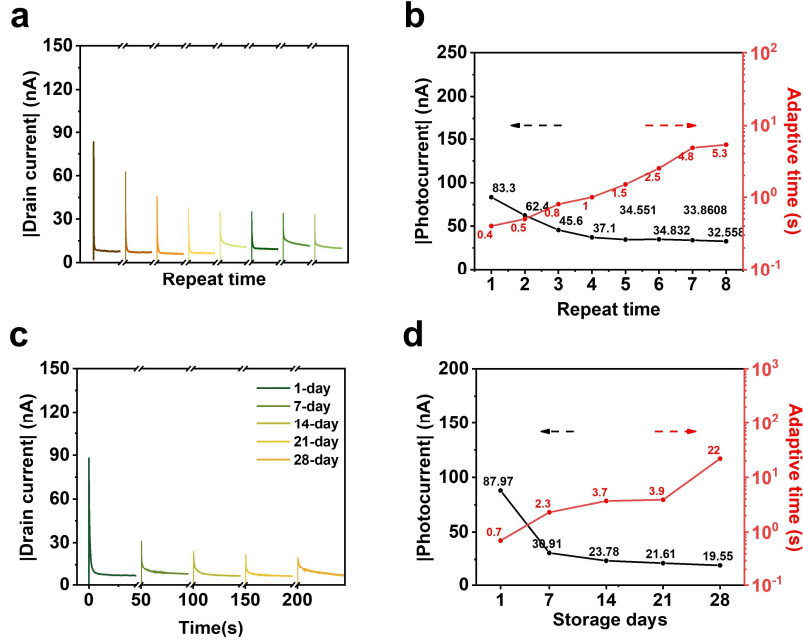
Supplementary Figure 26. Adaptive comparison of recently reported adaptive devices and our device. **a.** Comparison of all statistics. **b.** Statistical comparison by classifications. (The reference number corresponded to the manuscript)

Supplementary Table 6. Adaptive comparison of recently reported adaptive devices.

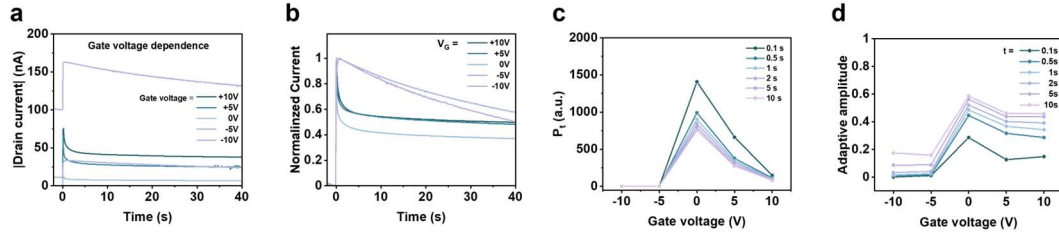
Active layer	Organic semiconductor	Stretchability	Tunability	Wavelength (nm)	Adaptive time (s)	Reference
2D MOF/ZnO heterostructure	No	Rigid	No	420	~ 10	<i>Chem. Mater.</i> 2023, 35 , 7144-7153
Bilayer MoS ₂	No	Rigid	Yes	660	~ 40	<i>Nat. Electron.</i> 2022, 5 , 84-91
QDs/ITZO	No	Rigid	Yes	550	~ 300	<i>Adv. Funct. Mater.</i> 2023, 33 , 2305959
IZO/MAPbI ₃	No	Rigid	Yes	659	~ 40	<i>Adv. Mater.</i> 2021, 33 , 2105485
In ₂ O ₃	No	Rigid	Yes	365	~ 7.5	<i>Nano Lett.</i> 2022, 22 , 3372–3379
graphene/PbS QDs/graphene	No	Rigid	Yes	1064	~ 100	<i>Adv. Mater.</i> 2022, 34 , 2205679
multilayer γ -InSe	No	Rigid	Yes	300–1000	~ 60	<i>Light: Science & Applications</i> 2023, 12 , 180
CsPb(Br _{1-x} I _x) ₃ /MoS ₂	No	Rigid	Yes	638	~ 180	<i>ACS Nano.</i> 2020, 14 , 9796–9806
CsPbBr ₃ /MoS ₂	No	Rigid	Yes	365	~ 4	<i>Adv. Funct. Mater.</i> 2021, 31 , 2010655
MoO ₃ /LiTFSI	No	Rigid	Yes	623	~ 50	<i>Nano Energy.</i> 2022, 97 107142
CsFAMA	No	Rigid	Yes	532	~ 40	<i>Adv. Intell. Syst.</i> 2020, 2 , 2000122
U6N-MOF/ReS ₂	No	Rigid	Yes	Polarized 860	~ 2	<i>Adv. Mater.</i> 2023, 35 , 2212118
C ₆ -BTBT	Yes	Rigid	No	400-750	~ 90	<i>ACS Nano</i> 2024, 18 ,13726–13737
C ₆ -BTBT	Yes	Rigid	Yes	365	~ 20	<i>Adv. Optical Mater.</i> 2024, 12 , 2303172
complementary BHJ	Yes	Rigid	Yes	400-750	~ 2	<i>Nat. Electron.</i> 2021, 4 , 522-529
CsPbBr ₃ QCM/DPP-TT CONPHINE film	Yes	100% Stretchable	Yes	365	10	<i>Nat. Commun.</i> 2024, 15 , 3123
DPP-DTT /N2200/PU	Yes	100% Stretchable	Yes	808	0.4	This work



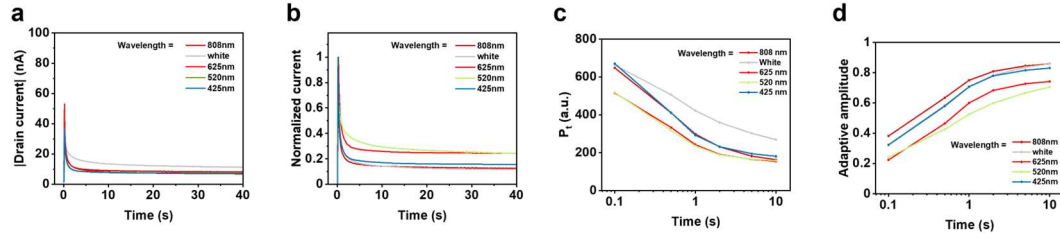
Supplementary Figure 27. Light-intensity-dependence adaptive behaviors of the ISNVaTs. **a.** The original I-T curves under different light intensity. **b.** The normalized I-T curves under different light intensity. **c.** The extracted P_t index under different light intensity. **d.** The extracted adaptive amplitude index under different light intensity.



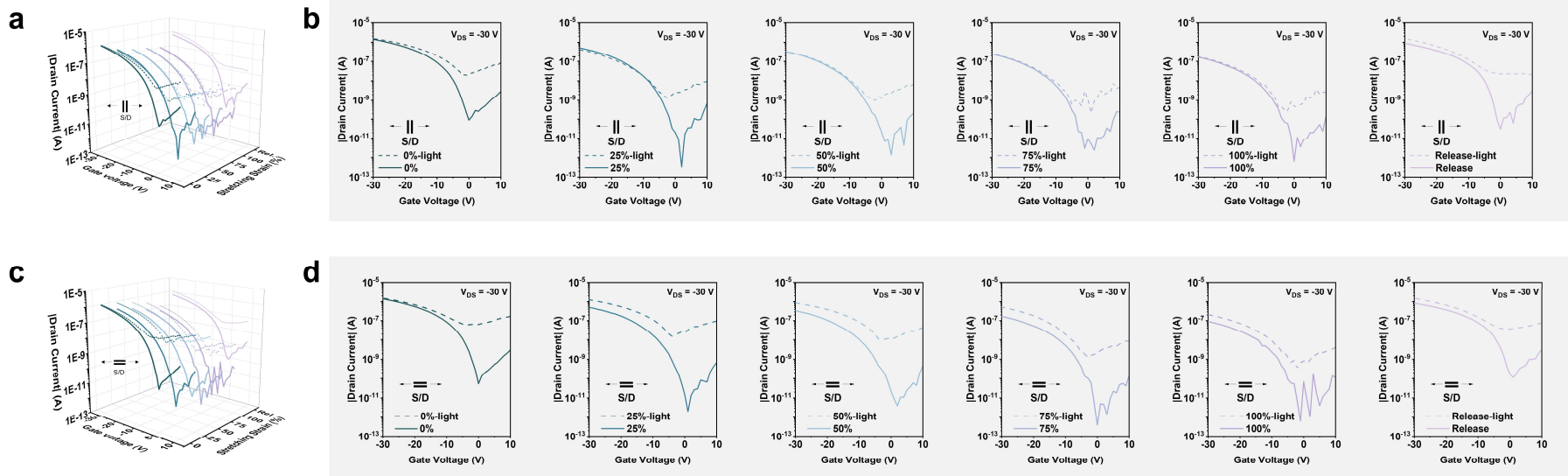
Supplementary Figure 28. a. Adaptation under continuous testing (808 nm, $P_{in} = 1050.14 \mu W cm^{-2}$). b. Extracted date of photocurrent and adaptative time under continuous testing. c. Adaptation under long-time storage. d. Extracted date of photocurrent and adaptative time under long-time storage. We applied 50-second continuous illumination each time with a 5-second interval and repeated the cycle four times. The results showed that although the maximum photocurrent did decrease, the adaptation time was still in an acceptable range. The reason for the attenuation could be that the filling of deep defects weakened the separation of photo-generated carriers, and continuous testing was insufficient to restore it. However, the devices demonstrated stable electrical properties in the dark state.



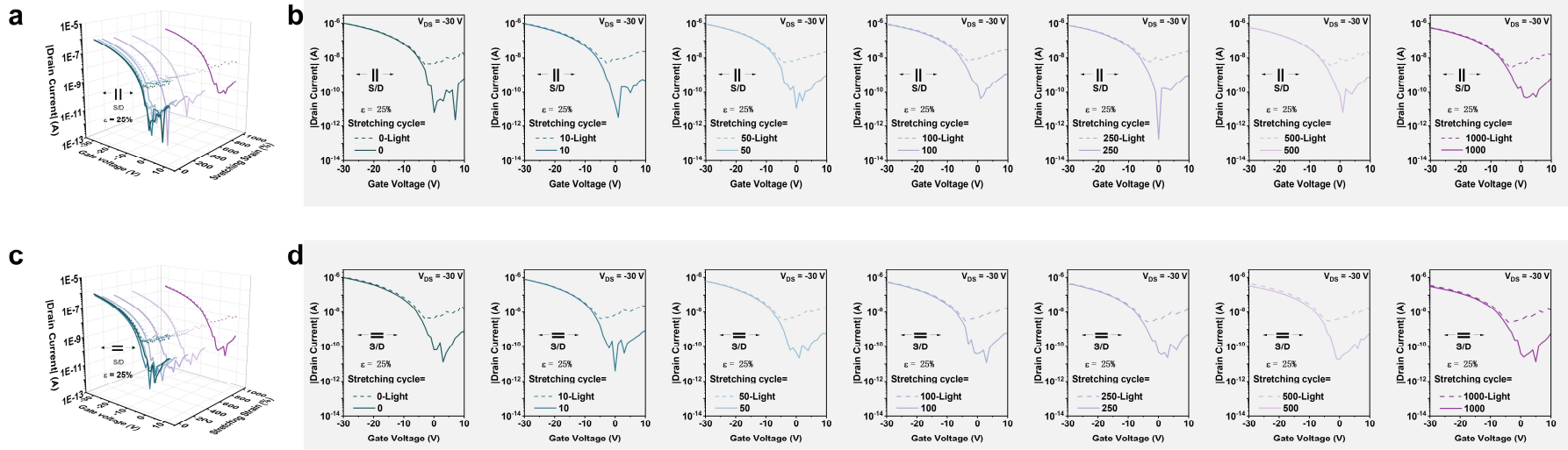
Supplementary Figure 29. Gate-voltage-dependence adaptive behaviors of the ISNVaTs. **a.** The I-T curves under different gate voltages. **b.** The normalized I-T curves under different gate voltages. **c.** The extracted P_t index under different gate voltage. **d.** The extracted adaptive amplitude index under different gate voltage. ($V_{DS} = -10 V$, 808 nm, $1050.14 \mu W cm^{-2}$)



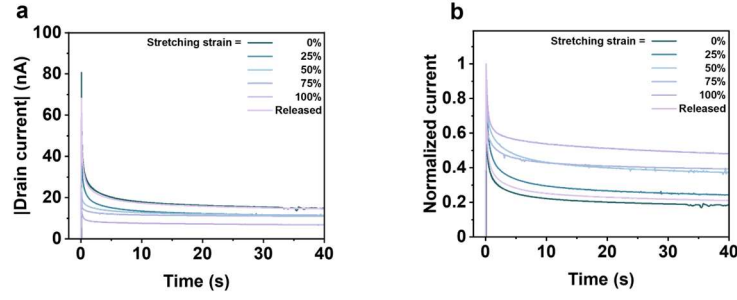
Supplementary Figure 30. Wavelength-dependence adaptive behaviors of the ISNVaTs. **a.** The I-T curves under different wavelengths. **b.** The normalized I-T curves under different wavelengths. **c.** The extracted P_t index under different wavelengths. **d.** The extracted adaptive amplitude index under different wavelengths. ($V_{DS}=-10$ V, $V_G=0$ V, $1050.14 \mu\text{W cm}^{-2}$)



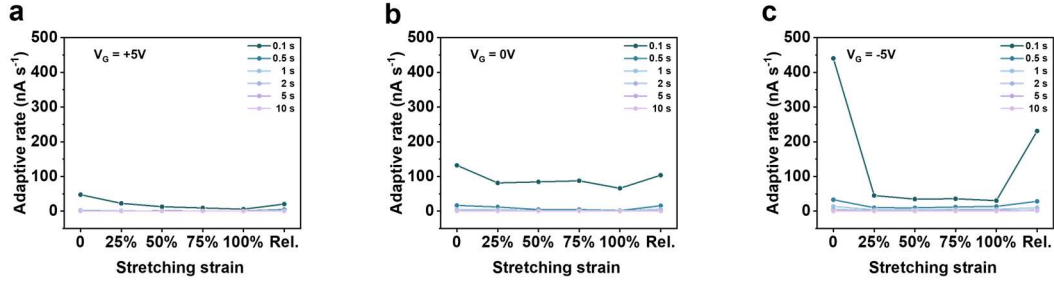
Supplementary Figure 31. Strain-tolerance characteristics and electrical stability characteristics against stretching strain of ISNVaTs. The ISNVaTs with MPSM photosensitive films were subjected to stretching strain from 0% to 100% in different directions, while the solid and dashed lines represented the current curves under dark state and light state, respectively ($V_{DS} = -30V$, 808 nm , $P_{in} = 1050\text{ }\mu\text{W cm}^{-2}$, V_G swept from $10V$ to $-30V$). **a.** Typical transfer curves under the stretching direction parallel to the charge transport direction. **b.** Independent transfer curves (parallel). **c.** Typical transfer curves under the stretching direction perpendicular to the charge transport direction. **d.** Independent transfer curves (perpendicular).



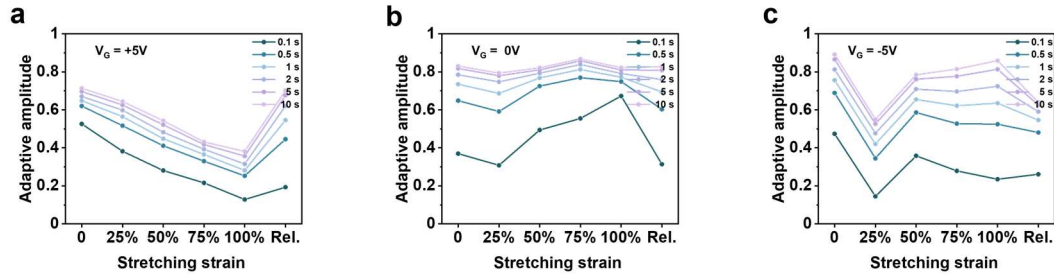
Supplementary Figure 32. Strain-tolerance characteristics and electrical stability characteristics against stretching cycle of ISNVaTs. The ISNVaTs with MPSM photosensitive films were then subjected to multiple stretching-releasing cycles up to 1000 times at 25% strain in different direction, while the solid and dashed lines represented the current curves under dark state and light state, respectively ($V_{DS} = -30\text{V}$, 808 nm , $P_{in} = 1050\text{ }\mu\text{W cm}^{-2}$, V_G swept from 10V to -30V). **a.** Typical transfer curves under the stretching direction parallel to the charge transport direction. **b.** Independent transfer curves (parallel). **c.** Typical transfer curves under the stretching direction perpendicular to the charge transport direction. **d.** Independent transfer curves (perpendicular).



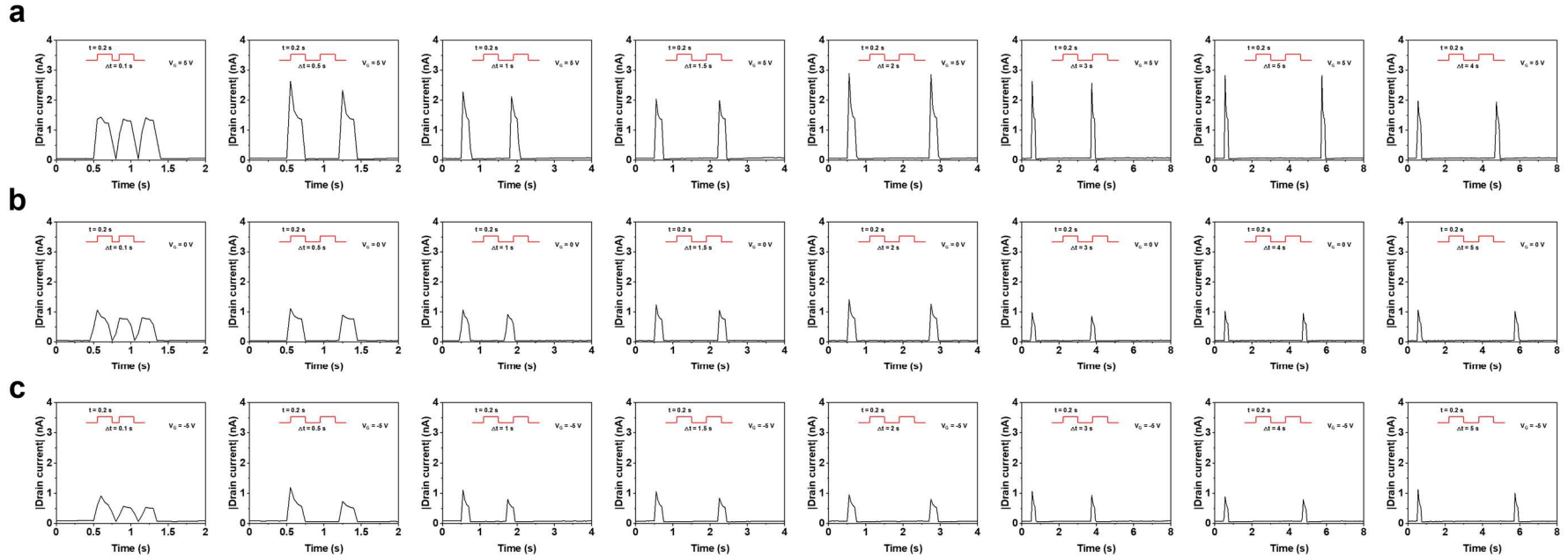
Supplementary Figure 33. Strain-dependence adaptive behaviors of the ISNVaTs. **a.** The I-T curves under different strains. **b.** The normalized I-T curves under different strain. ($V_{DS}=-10$ V, $V_G=0$ V, 808 nm, $1050.14 \mu\text{W cm}^{-2}$)



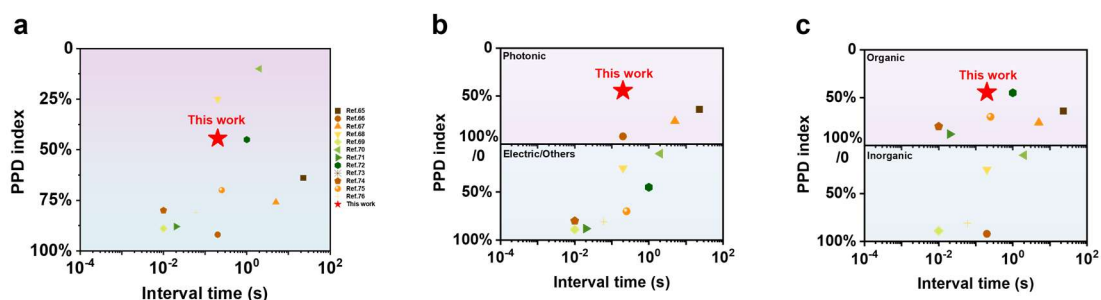
Supplementary Figure 34. The extracted adaptive rate index under different strains and gate voltages of the ISNVaTs. **a.** $V_G = +5$ V. **b.** $V_G = 0$ V. **c.** $V_G = -5$ V.



Supplementary Figure 35. The extracted adaptive amplitude index under different strains and gate voltages of the ISNVaTs. **a.** $V_G = +5$ V. **b.** $V_G = 0$ V. **c.** $V_G = -5$ V.



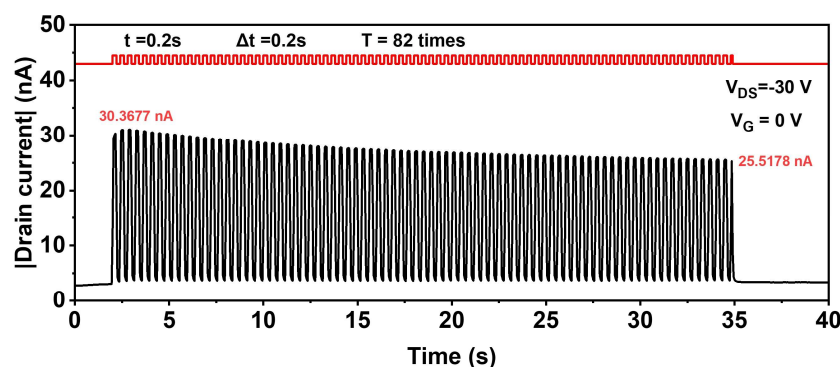
Supplementary Figure 36. Synaptic behavior at different time intervals and different gate voltages ($V_{DS} = -10$ V, 808 nm, $1050.14 \mu\text{W cm}^{-2}$). **a.** $V_G = +5$ V. **b.** $V_G = 0$ V. **c.** $V_G = -5$ V.



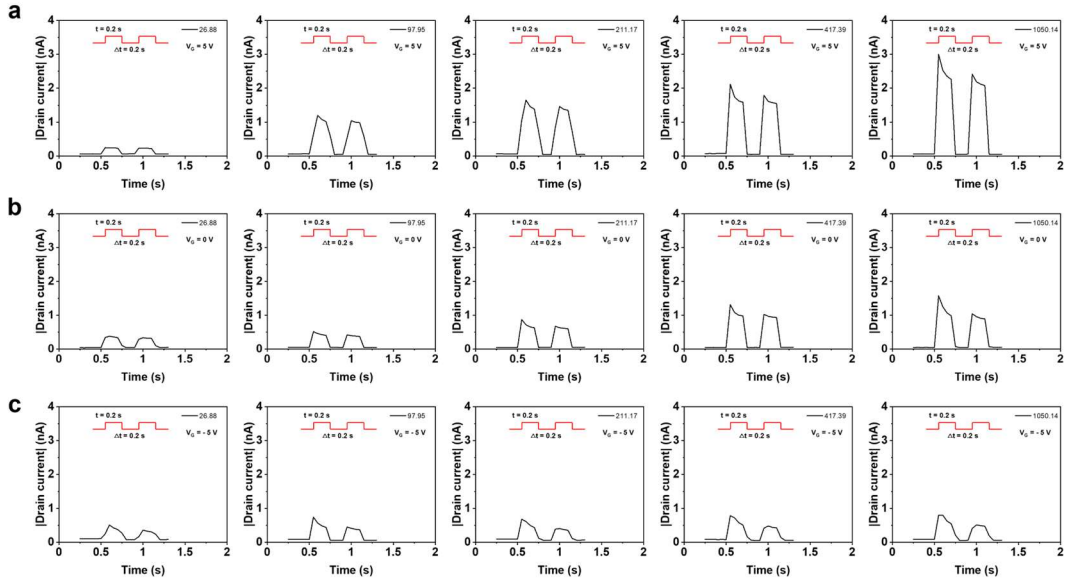
Supplementary Figure 37. PPD index comparison of recently reported synaptic devices and our device. **a.** Comparison of all statistics. **b.** Statistical comparison in different stimulation modes. **c.** Statistical comparison in active materials. (The reference number corresponded to the manuscript)

Supplementary Table 7. List of previously reported PPD synaptic transistors with our ISNVaT device.

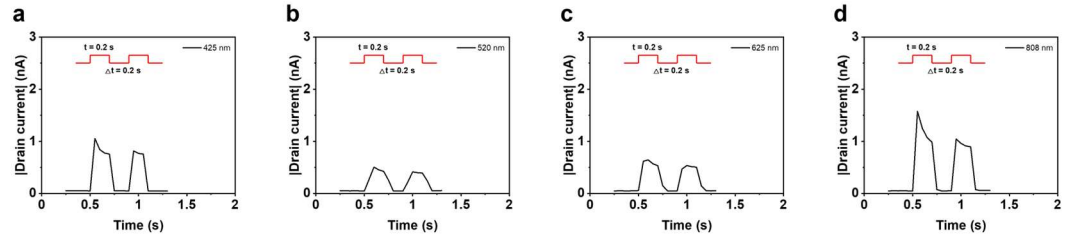
Active layer	Organic semiconductor	Stretchability	PPD index(%)	Δt (s)	Mode	Reference
DTAnt	Yes	Rigid	~ 64	23	P	<i>Trends Neurosci.</i> 2022, 45 , 884-898.
IGZO	No	Rigid	92	0.2	P	<i>Adv. Mater.</i> 2021, 33 , 2105017.
SnO ₂ /PVK	Yes	Rigid	~76	5	P	<i>Adv. Mater.</i> 2024, 36 , 2312831.
MoS ₂	No	Rigid	~25	~0.2	E	<i>Adv. Sci.</i> 2020, 7 , 1903480.
Ambipolar oxide	No	Rigid	89	0.01	E	<i>ACS Appl. Mater. Interfaces.</i> 2022, 14 , 22252–22262.
WSe ₂	No	Rigid	10	2	E	<i>Small.</i> 2021, 17 , 2103175.
PDPPBTI/ZnO	Yes	Rigid	88	0.02	E	<i>ACS Appl. Mater. Interfaces.</i> 2020, 12 , 15370–15379.
CNT	Yes	Rigid	~45	1	E	<i>ACS Appl. Mater. Interfaces.</i> 2022, 14 , 30124–30132.
HZO	No	Rigid	~10	5E-6	E	<i>ACS Appl. Mater. Interfaces.</i> 2021, 13 , 32005–32012.
PEFP	Yes	Rigid	~80	0.01	E	<i>Adv. Funct. Mater.</i> 2024, 34 , 2309910.
CNC/PEG/NaCl	Yes	Rigid	~70	0.25	O(humidity)	<i>ACS Nano.</i> 2023, 17 , 18883–18892.
IZO	No	Rigid	~81	0.06	E	<i>Materials Today Physics.</i> 2020, 15 , 100264.
DPP-DTT /N2200/PU	Yes	100% Stretchable	44.37	0.2	P	This work



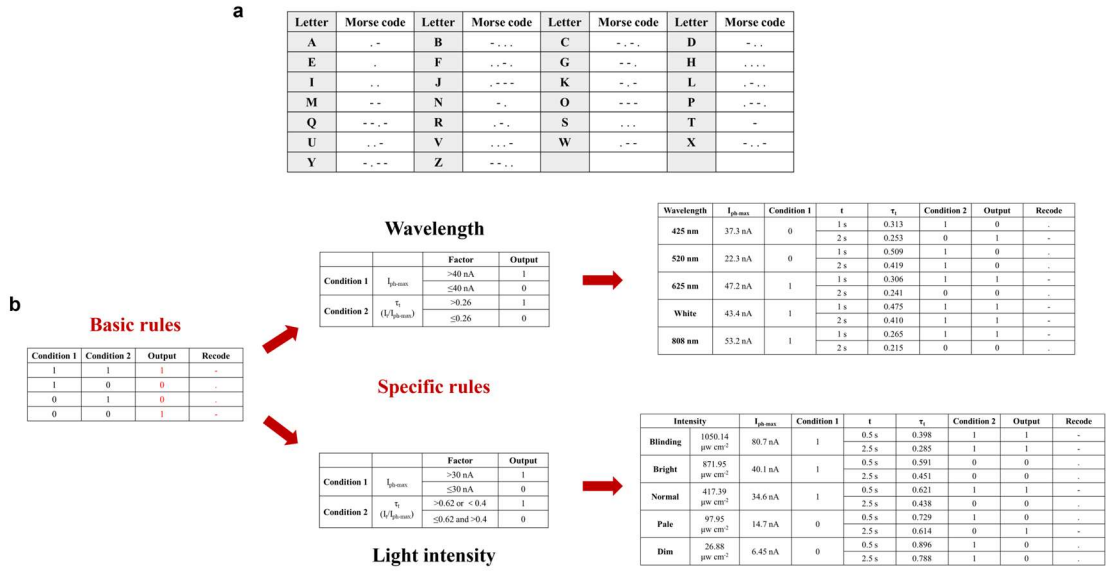
Supplementary Figure 38. Synaptic behavior at $V_{DS} = -30$ V. (808 nm, 1050.14 $\mu\text{W cm}^{-2}$, $V_G = 0$ V)



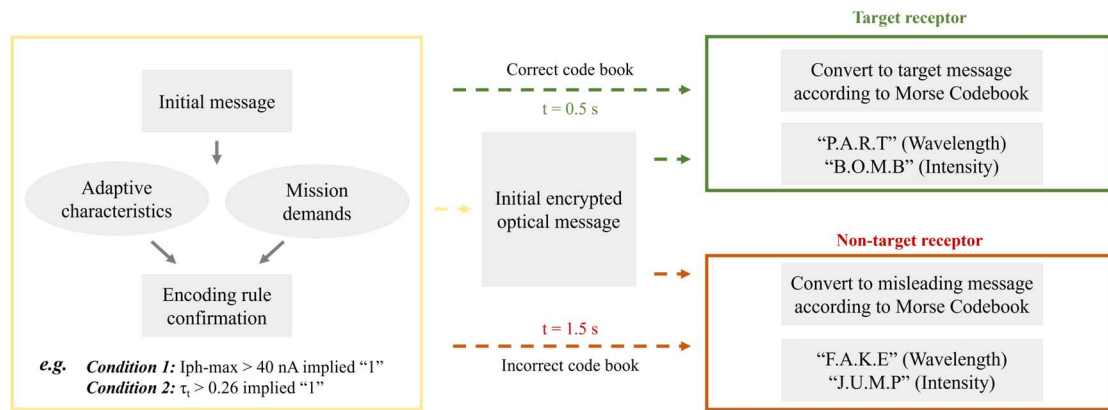
Supplementary Figure 39. Synaptic behavior at different light intensities and different gate voltages ($V_{DS} = -10$ V, 808 nm). **a.** $V_G = +5$ V. **b.** $V_G = 0$ V. **c.** $V_G = -5$ V.



Supplementary Figure 40. Synaptic behavior at different light wavelengths ($V_{DS} = -10$ V, $V_G = 0$ V, $1050 \mu\text{W cm}^{-2}$). **a.** 425 nm. **b.** 520 nm. **c.** 625 nm. **d.** 808 nm.



Supplementary Figure 41. Codebook for encrypted optical communication. **a.** International Morse code. **b.** Specific codebook for our adaptive devices at different wavelengths and light intensities.



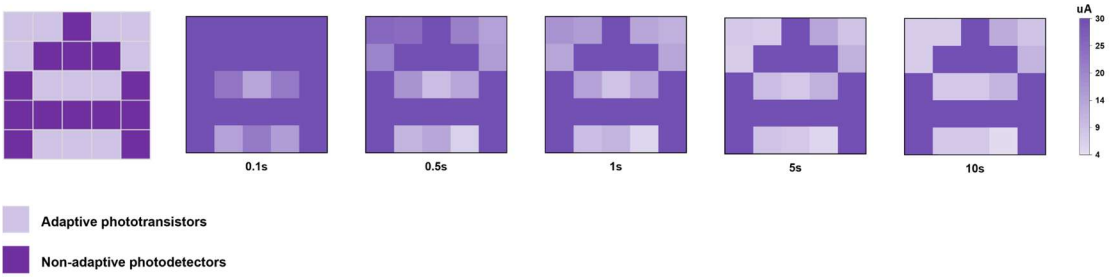
Supplementary Figure 42. The logic of the encryption scheme and encoding/decoding process.

True word	P				A			R			T
Morse code	.	-	-	.	.	-	.	-	.	-	.
Encoding (τ_1)	0	1	1	0	0	1	0	1	0	1	1
Wavelength	520	808	White	520	520	White	425	625	425	808	
False decoding (τ_2)	0	0	1	0	0	1	1	0	1	0	
False output	.	.	-	.	.	-	-	.	-	.	
False word	F				A			K			E

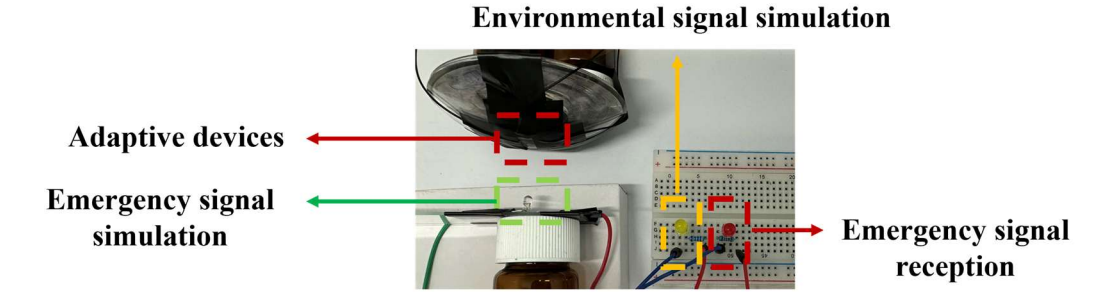
Supplementary Figure 43. Detailed coding and decoding for our adaptive devices at different wavelengths.

True word	B				O			M		B			
Morse code	-	.	.	.	-	-	-	-	-	-	.	.	.
Encoding (τ_1)	1	0	0	0	1	1	1	1	1	1	0	0	0
Intensity	Normal	Pale	Pale	Pale	Normal	Normal	Blinding	Blinding	Blinding	Normal	Pale	Pale	Dim
False decoding (τ_2)	0	1	1	1	0	0	1	1	1	1	1	1	0
False output	.	-	-	-	.	.	-	-	-	-	-	-	.
False word	J				U			M		P			

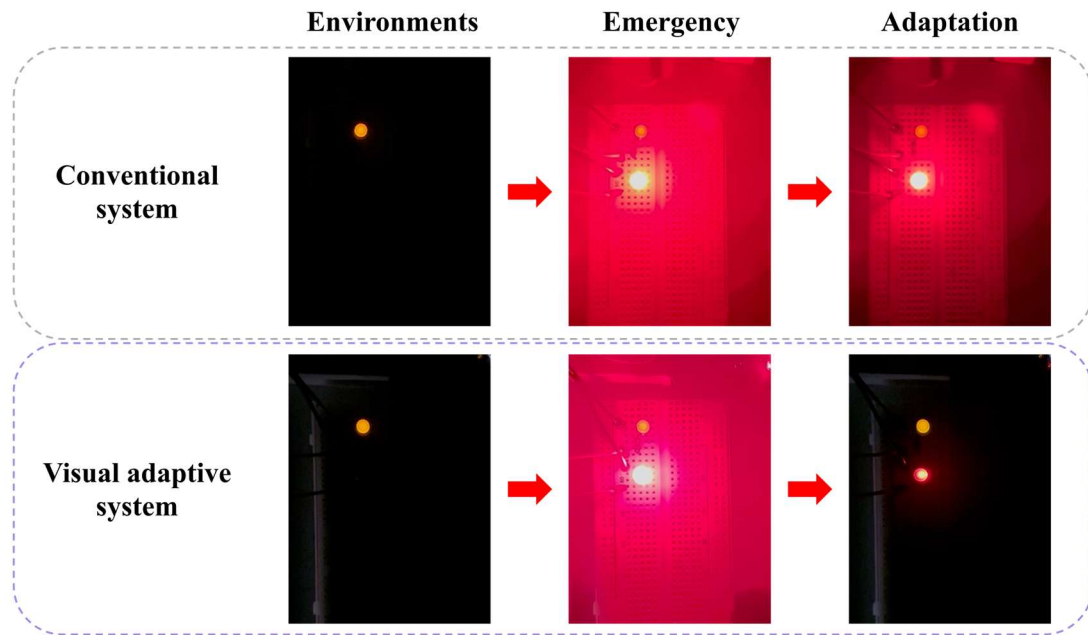
Supplementary Figure 44. Detailed coding and decoding for our adaptive devices at different light intensities.



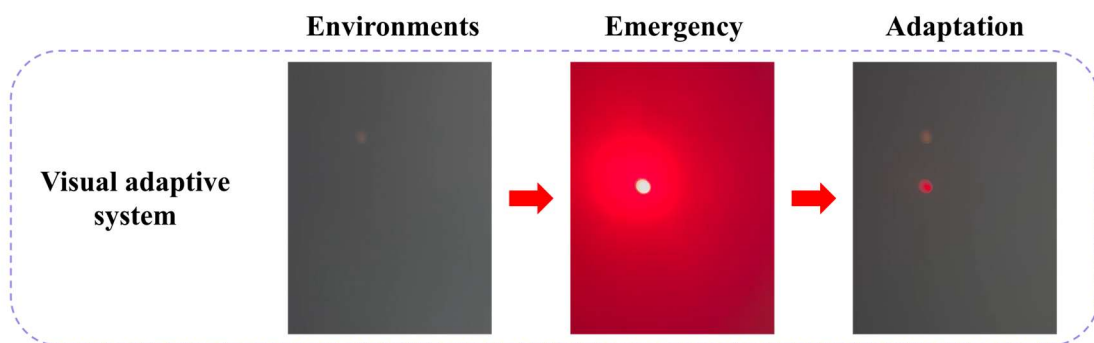
Supplementary Figure 45. Hotspot maps of 5*5 composite arrays of adaptive phototransistors and non-adaptive photodetectors under continuous illumination. ($V_{DS} = -10$ V, $V_G = 0$ V, 808nm, 1050 $\mu\text{W cm}^{-2}$).



Supplementary Figure 46. Actual picture of vision-adaptive pixel circuit and environmental reference.

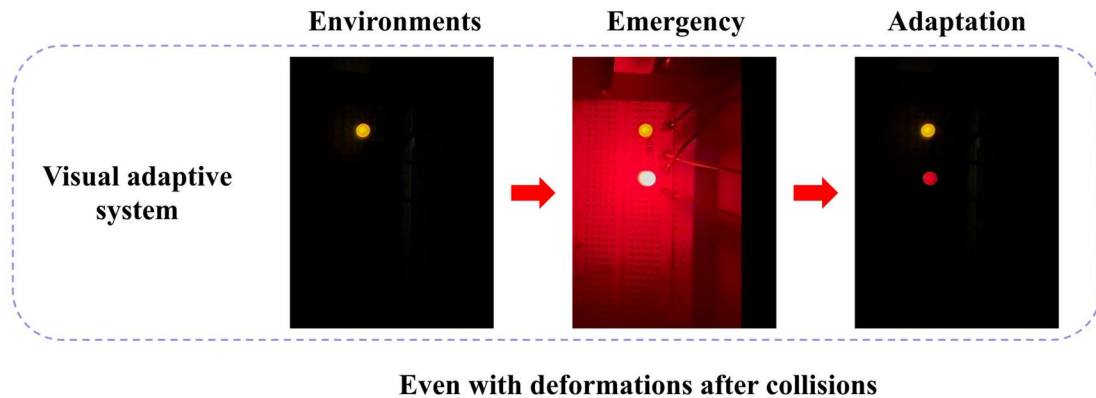


Supplementary Figure 47. ADAS simulation processes of conventional system and visual adaptive system. Due to the non-adaptive behaviors of conventional phototransistors under continuous illumination, environmental reference signals were covered and missed to some extent. However, the visual adaptive system ensured immediate treatment of emergencies and continuous attention to environmental signals.



Under extreme foggy conditions

Supplementary Figure 48. ADAS simulation processes under extreme foggy conditions. The high-quality delivery of NIR light allowed our visual adaptive systems to respond quickly to emergency situations and avoid lack of environmental information, even in foggy conditions.



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Supplementary Figure 49. ADAS simulation processes under deformation for some special causes such as collisions and crashes. The excellent strain-tolerance of our ISNVaTs-based visual adaptive systems gave the vehicle the ability to judge emergency situations and environmental signals promptly even in the event of severe deformation.

1 **Supplementary Reference**

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- 4 2. Vohra, V. et al. Transfer-printing of active layers to achieve high quality interfaces in
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13 Utilizing Poly(3-hexylthiophene)-Based Conjugated Block Copolymers. *Adv.Sci.* **9**, 2105190
14 (2022).